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ON

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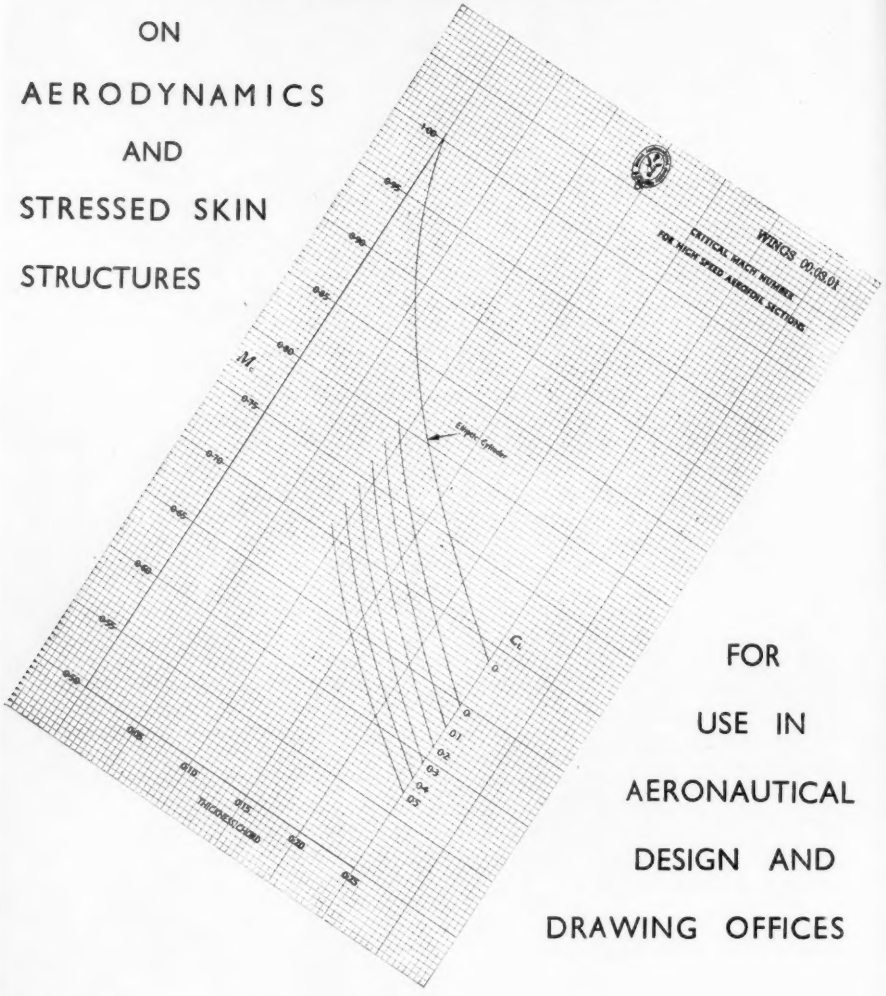

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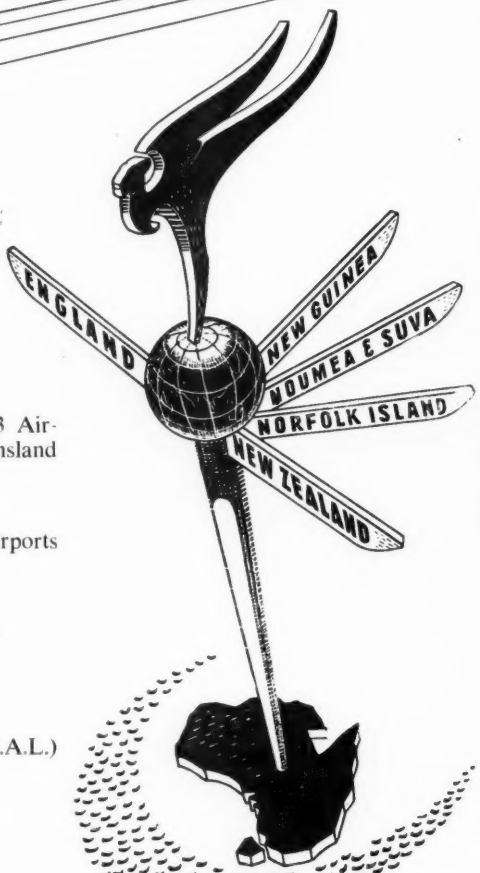

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British Gold Medal for Aeronautics

Awarded for an achievement leading to advancement in aeronautical science.

Simms Gold Medal

Awarded for the best paper read in any year before the Society on any science allied to aeronautics, *e.g.*, meteorology, wireless telegraphy, instruments.

The George Taylor (of Australia) Gold Medal

Awarded for the most valuable paper submitted or read during the previous session.

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Awarded to the designer of any invention or apparatus tending towards safety in flying; open to members or non-members.

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Awarded for some advance in aeronautical design.

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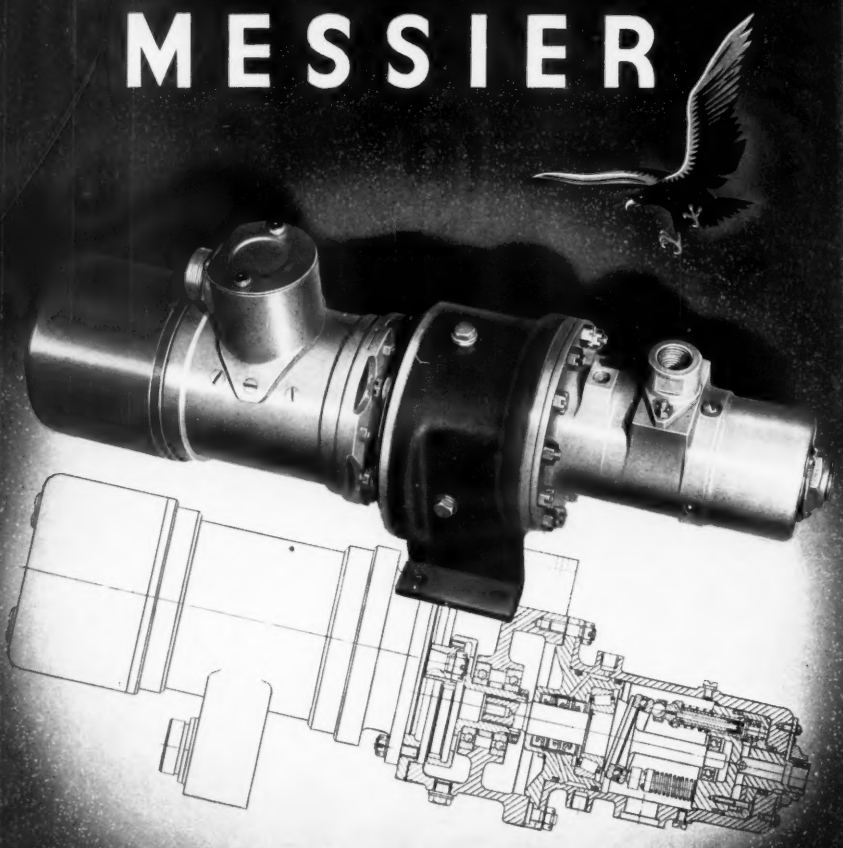

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COLD WEATHER OPERATION OF AIRCRAFT

by

G. W. WILSON, A.F.R.Ae.S., M.I.Ae.S.

and

Squadron-Leader E. P. BRIDGLAND, R.C.A.F., A.E., B.Sc., A.F.I.Ae.S., A.F.RAe.S.

1. INTRODUCTION.

IT IS many years since aircraft were first operated under extreme low temperature conditions, mainly by bush pilots pioneering the northern latitudes of Canada. The aircraft used were of the light and semi-medium type fitted with simple, low-powered engines. Consequently, crude methods could be adopted to keep them operating.

With the advent of high-powered boosted-engined aircraft, with their complexity and numerous complicated installations, together with other associated equipments, the difficulties became manifold and the earlier methods used were either impracticable or inadequate.

For this reason, some intensive testing and research has been done on the latest type of aircraft, engines and equipment, in an endeavour to solve the problems and, if not entirely successful, find what medium of success can be achieved with the least amount of subsidiary aid.

As opposed to temperate and tropical conditions, cold weather operation in itself presents many problems, some of which appear insurmountable, but with further experience and research, in due course these should be, if not entirely eliminated, reduced to a minimum. Operations in the field are extremely hazardous and always will be, and can only be lessened by the use of prudence and common sense, but unfortunately the latter tends to become latent under extreme low temperature conditions. Therefore, it is imperative that the aeroplane is built, equipped and supplied with suitable associated equipment to enable it to operate with the least amount of effort and subsidiary support.

The 753rd Lecture read before the Society on 21st October 1948 at the Institution of Civil Engineers, Great George Street, S.W.1. In the Chair, the President, Dr. H. Roxbee Cox, D.I.C., F.R.Ae.S.

Mr. Wilson is Senior Ministry of Supply Official, and Squadron-Leader Bridgland is Chief Engineering Officer at the Royal Canadian Air Force Winter Experimental Establishment at Edmonton, Alberta, Canada.

2. WEATHER DATA AND WIND CHILL FACTOR.

To understand how cold weather affects the functions of the aircraft necessitates a fund of knowledge as to what cold weather really is. As it can only be acquired by actual experience, it is beyond the scope of the authors to illustrate this effectively, but an effort will be made to explain its effect as far as possible.

Extreme low ground temperatures are usually associated with large areas of more or less flat country far dispersed from large areas of exposed water and temperatures of the order of $-50°C.$ are quite common (Fig. 1). In addition, high winds are experienced and snow-falls are mostly of a moderate nature, but drifting snow can prevail for very long periods. Combined high wind with low temperatures not only produces blizzards and negative visibility, but also what is known as "Wind Chill"[1]. This is the worst form of cold weather to encounter, as not only does it cause exhaustion, low morale, pain and frustration, but in some cases the lack of the will to live when the wind chill factor is unusually high (Fig. 2).

Wind chill is the measure of the quantity of heat which the atmosphere is capable of absorbing within an hour from an exposed

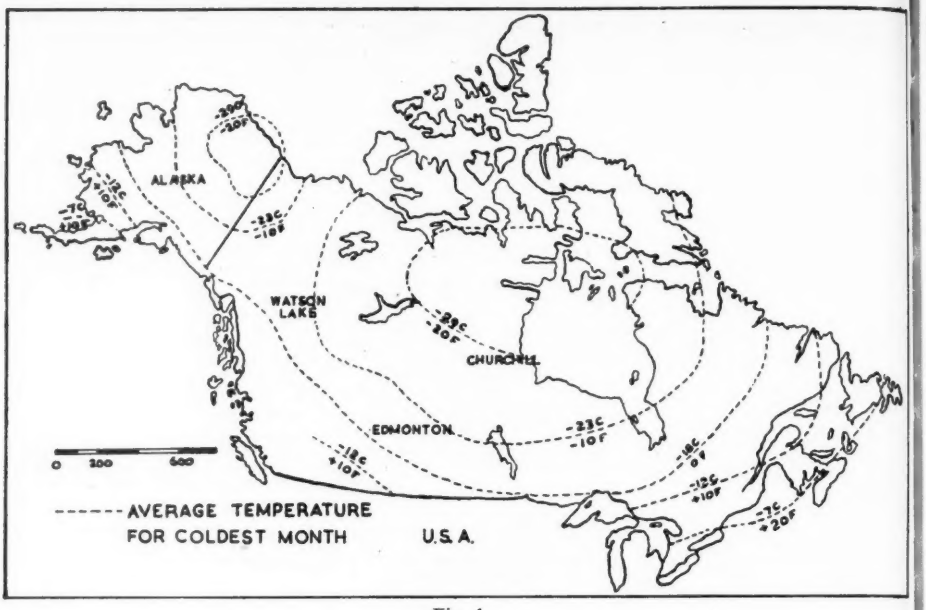


Fig. 1.
Average temperature for coldest month, Diminion of Canada.

surface one metre square (or equivalent to 10.75 square feet). For the sake of correlating heat loss with the customary values used by physiologists to express human heat production and food requirements, the quantity of heat transferred is expressed in kilogramme calories per square metre per hour (0.0369 B.T.U. per ft. sq. per hour). The formula developed by Paul A. Siple, Ph.D., and Charles F. Pascall of the U.S. Antarctic Service was derived from a large number of experiments based upon carefully measuring the freezing time of a cylinder of water exposed in open atmospheric conditions which varied widely in temperature and wind velocity. The measurements were made under calm skies during the Antarctic winter night. The formula adopted was:

$$Ko\,(\sqrt{WV \times 100} + 10.45 - WV)\,(33 - Ta)$$

in which

Ko = total cooling in kilogramme calories/sq. metre hr.

WV = Wind velocity in metres/sec.

Ta = Temperature of air in °C.

At low wind velocities the cooling rate changes greatly with slight variation in wind velocity. Therefore the reliability of the values decreases as a state of calm is reached. Wind chill expresses the rate at which a body of a naked human being would lose heat if placed outdoors under given conditions. This value is calculated on the assumption that skin temperature remains at the comfortable level of 91.4°F. In actual fact, the skin temperature falls on account of loss of stored body heat with the rate of cooling dropping accordingly. The formula indicates the strain on the human body in maintaining a constant temperature with varying air temperatures. In order to maintain a constant comfortable skin temperature of 91.4°F., the rate of heat delivery by the body to the skin must equal the rate of cooling. At air temperatures above 91.4°F., excess heat is dissipated from the body by evaporation. Therefore the humidity factor does not affect the formula except when the surrounding air approaches the saturation point.

From Fig. 3 it will be seen that human flesh under this formula freezes at a factor of 1400. Apart from the effect on the efficiency of the human element, wind chill also makes its presence known on the aircraft, whereby the warming up rates of engines and

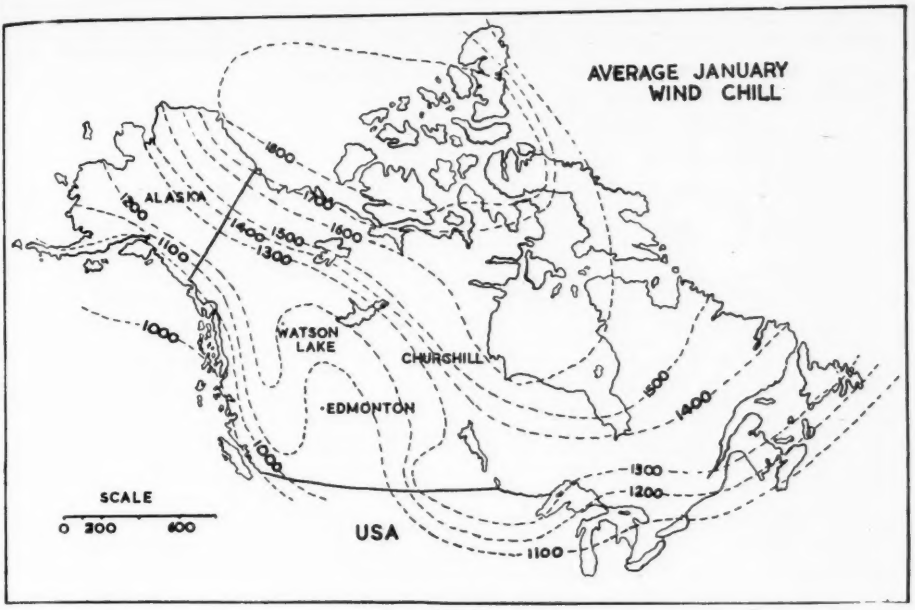


Fig. 2.
Average January wind chill, Dominion of Canada.

installations are greatly retarded and conversely, the cooling accelerated.

Although wind chill has been accepted in parts of North America as a measure of cold, there is still some doubt among many of its entire reliability, but as far as aircraft operation and its effect on personnel is concerned, there is no doubt that it has a great influence. As mentioned before, extreme low temperature does show its mark on the efficiency of the human being and there is a great belief among certain operators that the efficiency drops 2 per cent. per degree fall below zero Fahrenheit without any regard to wind speed.

The authors are sceptical in this regard; in fact, assuming this theory to be correct, and disregarding wind speed, a person would be only 50 per cent. efficient at $-31.7°C.$, assuming he was 100 per cent. efficient under temperate conditions. As most of the cities and townships in the prairie belt of North America experience $-31.7°C.$ quite often over long periods, it would be taken that the whole of the population when outdoors would be in a 50 per cent. state of efficiency. To enlarge further, at $-37.2°C.$ one would possess 30 per cent. efficiency, a sorry state of affairs. The authors have experienced temperatures as low as $-45°C.$ and although their efficiency was impaired, they still considered themselves fairly stable, whereas from the aforementioned theory, they should have been most irrational. It is known that at low temperatures much depends upon a person's physical and mental condition and these vary with each individual. For instance, an average person can be taken into a $-30°C.$ and lower zone and show signs of inefficiency, whereas a none-too-brilliant person will display far more intelligence and energy superior to that normally shown under temperate conditions. Therefore, the yardstick above cannot be taken too literally.

3. TERRAIN AND ARCTIC TOPOGRAPHY.

It was intimated previously that low temperatures are usually associated with large areas of land, which means that in most cases large populations are widely dispersed and in fact, habitation becomes very sparse at the most northern latitudes. From this it can be seen that airfields and bases, meteorological stations and radio aid stations likewise

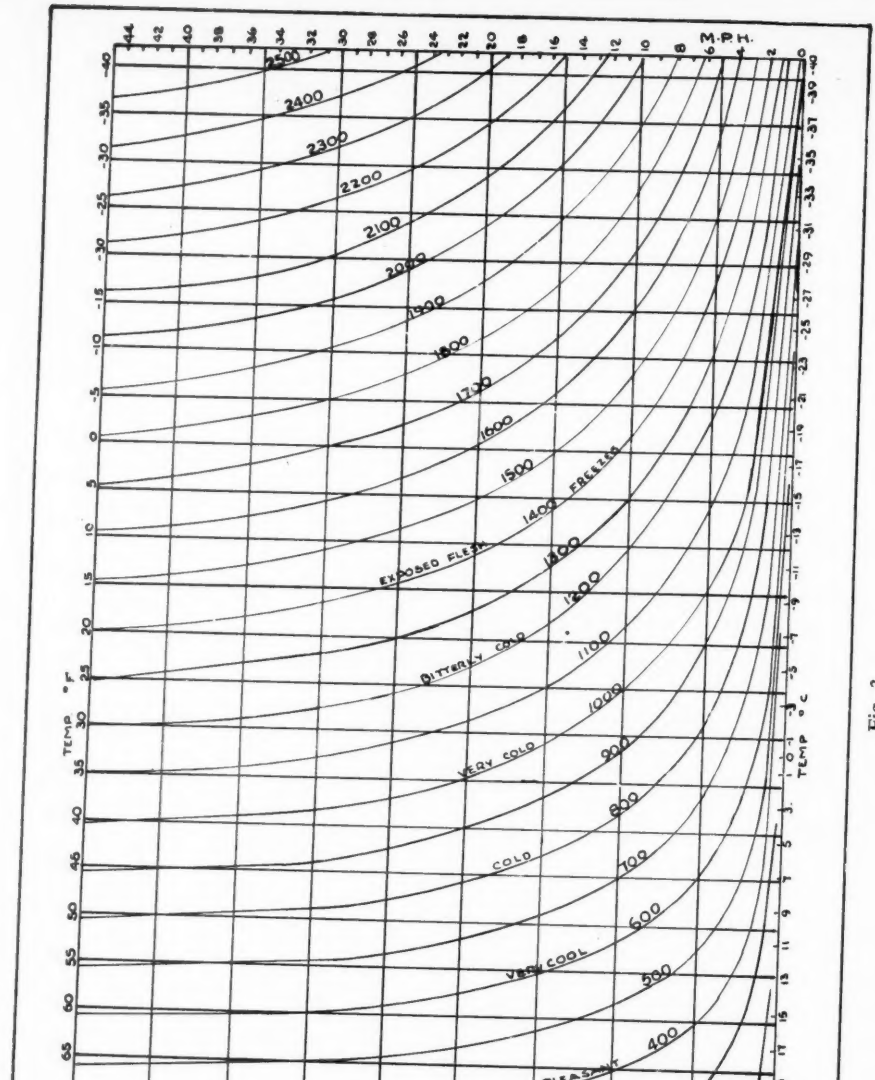


Fig. 3.
Wind chill factor.
Wind velocity in metres per sec.

become dispersed, the latter almost non-existent. Although meteorological information is reasonably accurate, forecasts are often changed with great frequency because of the various influences which prevail over the water and land areas in the northern latitudes. With a combination of the above, operations become critical.

Snow-packed airfields, landing grounds and so forth, present a problem in relation to operating the aircraft, especially for landing when overcast conditions prevail. No horizon exists and ground height is difficult to judge. This is usually overcome by having small markers or trees disposed on the sides of the runways protruding above the snow level. This expedient is of no use when blowing snow conditions prevail which can obscure all signs of terrain, even though the upper levels may be clear. Landing in this instance is practically impossible with any degree of safety.

PART I. AIRCRAFT

4. SERVICES.

4.1. General.

It is generally thought that the fundamental difference between aircraft flying at altitude in temperatures around $-40°C$. and aircraft taking off from bases under sub-zero temperatures, is the engine starting problems connected with the latter.

This is not strictly true and becomes evident when actual experience on both is acquired. In the case of the former, the aircraft is not subjected to these low temperatures at altitude for periods long enough for the whole structure and installation to become soaked and stabilised at the temperatures encountered, whereas taking-off, the aircraft begins the flight soaked at the prevailing O.A.T. and maintains that temperature when at altitude. The flight through the inversion stage is so brief as to be almost non-effective and only those components and installations in and around the vicinity of the power plant become subjected to higher temperatures to any degree.

From this it can be realised that the performance of the aircraft structure, components, installations and various services, although invariably satisfactory in the former case, are prone to develop trouble in the latter case. This will be more noticeable when enlarged upon later, with the various items such as propellers, plastic hoods, instruments, controls, and so on.

When parked under Arctic winter conditions aircraft are mostly in the open, hangars being few and far between, and the clearance of snow, ice and frost from the aircraft presents quite a problem. This can be partly solved by the use of properly fitted covers and blanking plates. The use of engine, and particularly wing, covers on large aircraft is somewhat of a difficulty unless they are easy to handle in high winds; they must be light in weight and moisture repelling. The fastening devices must also be easy to handle with heavy gloved hands, natural rubber bungee with large hooks and eyes, or cords combined with large hooks, being the most suitable.

Blowing Arctic snow finds its way into any small hole or crevice and seems to be more difficult to repel than desert sand. If the snow is allowed to accumulate and remain in locking devices, micro-switches, control hinge points, bomb bays, flaps and propeller spinners, malfunctioning is bound to occur (Figs. 4 and 5). The aircraft should be parked with bomb doors closed and flaps up. Special linen covers for the protection of other mechanisms are essential.

Plastics do not stand up to the rigours of low temperatures, usually because of contraction and increased brittleness. Unless ample clearance is provided at the attachment points and local stresses are removed, any slight load will produce cracks, fractures and total collapse. This applies particularly to transparent plastic canopies and hoods which are subject to handling on the ground and air loads when the aircraft is airborne.

4.2. Lubrication.

The correct type of lubrication on aircraft plays an important part, especially in the functioning of controls. The use of a high melting point grease will adversely affect the frictional loads, especially on the large type of aircraft. Experience has shown that for mechanical controls and races, grease to Specification D.T.D. 539 is very satisfactory. Because of its high viscosity index, it is necessary to increase the frequency of re-greasing when the aircraft is subjected to milder temperatures, such as housing in a

Wind chill factor.
Wind velocity in metres per sec.

heated hangar. For wheel bearings, D.T.D. 577 grease has shown no adverse effects, being satisfactory at the low temperature range and the high temperatures produced when taking-off and landing.

4.3. Control systems.

The behaviour of the present type of controls employing cable with chain and cable pushpull rod systems is unsatisfactory and more so on large aircraft.

On large aircraft the trimmer controls become excessively slack and the main controls also develop slackness (see Fig. 6). This can be improved by the introduction of tensioning devices or, better still, by the incorporation of controls having the same coefficient of expansion as the bulk structure of the airframe. On small aircraft, where steel has been employed in the system, differential expansion has been known to take place and the control surfaces have moved from their original setting to a very large degree.

The slackness can be offset by giving a higher initial tensioning at temperate conditions, when it will still retain sufficient tautness at low temperatures, but this method is far from satisfactory as over-tensioning may be exceeded beyond the design limitations.

4.4. Hydraulic systems.

The trouble connected with hydraulic systems under Arctic conditions is usually on the ground when the aircraft has been dispersed overnight. Normally the trouble is confined to leaking glands, although internal seals have been known to fail. Those systems employing natural rubber seals and glands give less trouble because they harden and stiffen at much lower temperatures than the synthetic type. The systems on large aircraft where greater bearing surfaces are used also give less trouble.

Non-metallic pipe lines, if fitted on moving parts of the hydraulic system, frequently produce leaks at the end fittings due to loss

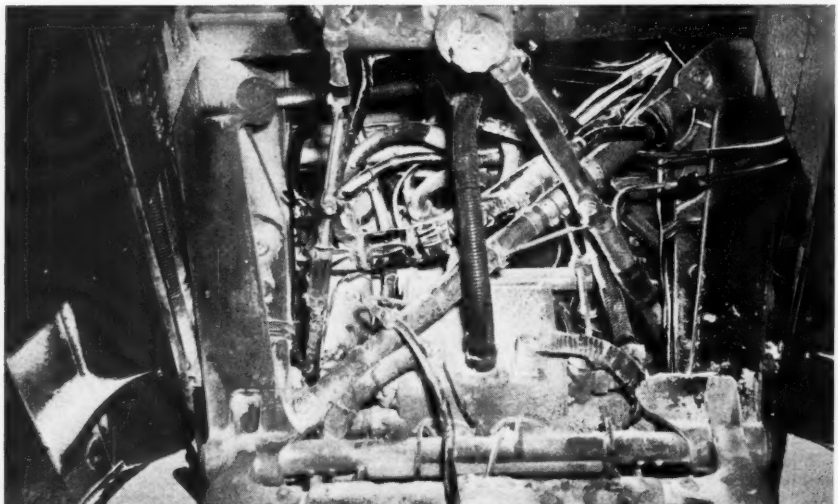


Fig. 4.
Forward end of undercarriage nacelle on a Lincoln packed with drifting snow.

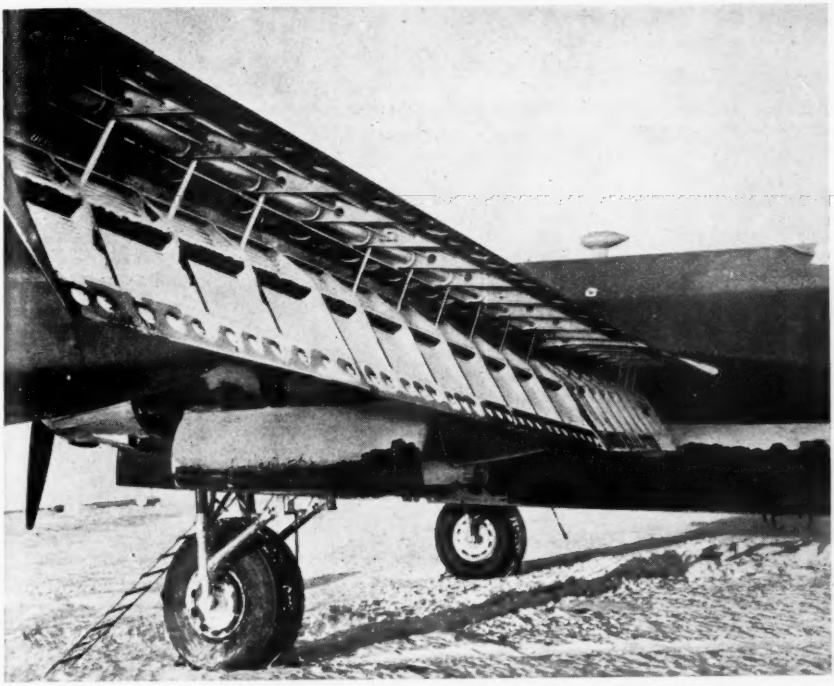


Fig. 5.
Flaps and mechanism on a Lincoln packed with drifted snow.

of flexibility and being subjected to deformation during the operation of the system.

The present types of hydraulic pumps give little or no trouble at low temperature, but accumulators embodying air with fluid chambers are often affected.

Comparative time tests between operation of components at low temperatures and temperate conditions show a negligible increase at low temperature ranges.

4.5. Pneumatics.

The pressure maintaining capabilities of all aircraft pneumatic systems are generally poor when the aircraft is on the ground under low temperature conditions. Systems embodying rubber sealing rings on the pipe line unions give the more serious leakage. Moreover, loss of pressure takes place from the pneumatic rams fitted to the engine services, but this can be avoided by the incorporation of an isolating cock.

In spite of these serious leaks, once the aircraft becomes airborne normal pressure is maintained in the system, which implies that the engine-driven compressors have ample capacity and it is only when the aircraft has been dispersed long enough for the system to get soaked at the prevailing low O.A.T.'s that the loss materialises.

By introducing a Methanol anti-freeze installation into the pneumatic system the possibility of ice formation and failure of components is reduced, but the application of heat to the oil and water traps before draining is still necessary to liquify the oil and melt any ice that may have formed in the base of the traps.

4.6. Electrical systems and components.

Once the engine, or engines, have been started and the aircraft becomes airborne, low temperatures have little or no effect on

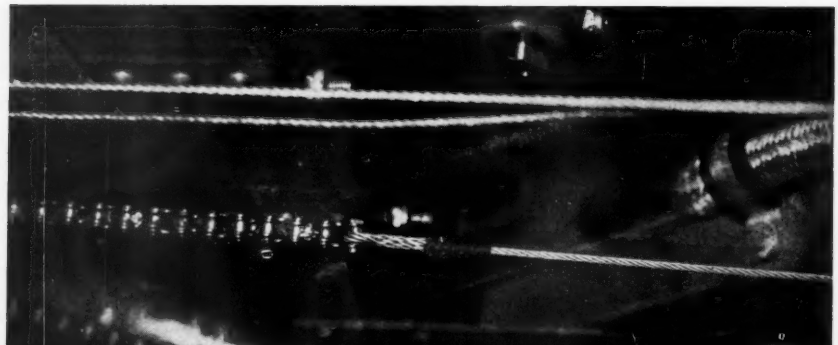


Fig. 6.
Slack trimmer cable.

the electrical systems. Before this is achieved, however, they are a matter of some concern. Failure of the system may cause a complete breakdown of operations and extended unserviceability. The main items concerned are:—

(*a*) Batteries
(*b*) Cables
(*c*) Engine starters.

As is well known, batteries lose their capacity according to the degree of low temperature to which they are exposed and cannot be charged at the normal rate; therefore, if they cannot be maintained in a heated condition, they should be kept fully charged at all times.

For this reason slave batteries, *i.e.* ground starter battery units, are universally used for starting engines instead of the aircraft batteries, except at isolated bases or after forced landings. To provide for this latter event it is essential that some form of battery heating be supplied. Dry cell batteries lose all charge at low temperatures and are most unreliable on aircraft systems.

Limited tests over the past winter (1947-48) on alkaline accumulators (24 and 2 volt) indicated that they withstand temperatures down to – 30°C. to a greater extent than the lead acid type and also require less servicing. It is hoped to obtain more data on this type of accumulator at lower temperatures in the near future. During a mean temperature of – 14°C., 84 consecutive engine starts were obtained on a Meteor 4 aircraft. It would also appear that the electrolyte does not freeze at extreme low temperatures if the specific gravity of the electrolyte is kept normal. Fig. 7 indicates the results of an 18-hour exposure test on a type L.23 accumulator.

Synthetic insulating material used on the cables is affected greatly by hardening and

Time, hrs.	Temp. °C. O.A.T.	Electrolyte	S.G.	State of Electrolyte
Zero	– 20	– 7	1.250	Fluid
3	– 25	– 11	1.250	Fluid
6	– 28	– 18	1.260	Fluid
9	– 30	– 27	1.255	Fluid
12	– 31	– 29	1.260	Fluid
15	– 30	– 29	1.260	Fluid
18	– 27	– 28	1.260	Fluid

Fig. 7.

becomes very brittle at low temperatures. Any form of handling or adjustment requires the application of heat to the cable, otherwise the material will crack and even break off in large pieces, leaving the bare wires exposed. This is particularly so on aircraft equipped with folding wings.

Because of more frequent and repeated engine starting and the higher torque loads caused by engine stiffness, the life of starter motors is shortened somewhat, not necessarily electrically, but more with the mechanical unit such as shearing of the teeth on the gearing. Automatic starting systems such as are used on gas turbine-engined aircraft do not appear to be affected by low temperatures, nor is a time lag of any importance apparent when they are in operation.

Most of the remainder of the major components such as relays, voltage regulators, cut-outs and circuit breakers, appear to withstand the low temperatures reasonably well, provided that they are screened from the elements.

Finally, it is important to have the ground flight switch situated away from the slipstream as the operator is in danger of being frozen when the engines start up.

4.7. Instruments.

Most instruments appear to operate almost as well at low temperatures as they do under temperate conditions, the main cause for complaint being condensation and faulty lubrication. An exception to this are the engine oil pressure gauges, compasses, clocks and watches.

In the case of the former, these are mainly the transmitting type using oil as the transmitting medium and true oil pressures are not always indicated, especially when engines are first started. Liquid-type compasses produce bubbles in the fluid, often to such a large degree that the application of heat will not remove them.

At temperatures below 0°C., clocks and watches begin to show signs of inaccuracy.

4.8. Undercarriages.

Undercarriage oleo shock struts in the main operate reasonably satisfactorily whether using a mineral or castor based fluid. In one particular case, however, an aircraft with a mineral based fluid and synthetic seals did display oleo trouble, so much so that the aircraft could not be moved at temperatures lower than −20°C. because of the excessive leakage past the seals.

For cold weather operation it is preferable, in fact, essential, to reduce the duplication of stores and spares, and other such items. Therefore, all aircraft should be standardised and operate on one type of fluid and seals. A mineral base fluid is preferable as, in an emergency away from supply points, it can be made up from engine lubricating oil and kerosene.

It has been found that during engine running at the chocks and when taxi-ing, fine minute particles of ice get impinged on to the oleo struts which eventually find their way inside the lower seals, thereby destroying the sealing properties. To avoid this, gaiters or scraper rings need to be fitted around the telescopic tubes. Preference is given to the gaiters in that they are easy to maintain and readily replaceable, whereas the scraper ring requires close and frequent inspection for wear.

Oleo strut extensions vary considerably with temperature when incorporating oil and air to absorb the shock loads and require a greater volume of air at low temperatures to maintain the recommended extension; therefore, the manufacturer should incorporate a temperature compensation diagram in the maintenance manual, to guide maintenance personnel in this respect.

With the exception of the previously quoted example, leaking of the fluid is very slight and the shock absorbing qualities are adequate at the most severe temperatures, but if the same system is used over a second winter period, the efficiency deteriorates markedly and usually a renewal of working parts is necessary.

The type of undercarriage oleo struts comprising rubber pads for the shock loads have, surprisingly, given satisfaction at low temperatures, although it is known that the rubber pads have hardened. When taxi-ing to take-off position, the aircraft have behaved reasonably well, only slight roughness being felt. In landing with twin-engined aircraft, with which type experience has been gained, no noticeable difference has been felt from temperate conditions. This is attributable to the undercarriage being tucked away in the nacelles at the rear of the engines, where the temperature is well above the O.A.T.

Synthetic tyres behave reasonably well at low temperatures, although flat spots develop when the aircraft has been stationary for several hours. The deflection usually disappears if the taxi-ing distance is of any considerable length. If the tyres have been inflated under temperate conditions, they must be further inflated to the desired pressure after entering the low temperature zone. Treaded tyres are far superior to the smooth types for maintaining a grip on snow-packed surfaces. Ice grip tyres show a slight improvement over the treaded type when used on icy surfaces.

To avoid freezing of the inflation valve, it is essential to ensure that the cover cap is always in place and to use dry air for inflation.

The usual practice of parking aircraft with the brakes "ON" leads to countless trouble under low temperature conditions. Apart from the brakes freezing in the "ON" position, stiffening of the expander bag takes place and when the aircraft is moved, the base of the brake shoes tends to destroy the outer skin of the expander bag.

4.9. Cabin and cockpit heating.

The requirements in A.P. 970 call for a minimum temperature of 18°C. at crew stations on military aircraft. Temperature tests made on various aircraft show that they do not meet this requirement, mainly because of faulty distribution of the heat available in the system. This has not caused much concern because flying crews and Service passengers flying under Arctic conditions must be clothed suitably to enable survival in the event of forced landings and therefore, specially dressed for this purpose they will find 18°C. far too warm. From experience gained on different types of aircraft, the crew stations or cabin temperatures should be limited to a minimum of 0 to −5°C., particularly in fighter aircraft where the crew cannot divest themselves of any clothing while in flight. An exception to this, however, is the navigator's position on large aircraft. This member of the crew needs to work his instruments with bare hands and some form of additional heat is necessary. Further, the navigator's table requires surface heating. Limited tests on the latter have been conducted using electro-thermal heating and showed promising results.

The main problem concerned with inadequate heating of cockpits and cabins is chiefly at the beginning of the flight. It is found that excessive misting and frosting of windshields, canopies and similar items, takes place soon after the crew enter the aircraft. This is caused by the formation of condensate by the crew breathing in close proximity to the windshields and so on. Therefore, a hot air spray is required which can be directed on to the affected parts, but which would not have to rely on ram effect for supply.

PART II. ENGINES

5. SERVICES.

5.1. General.

Engine operation at low temperatures is discussed in the following sections, which deal with the different systems forming a complete engine installation. As no one system is completely independent of the others, some cross reference is necessary, but so far as possible each system is discussed independently of the other. As the Paper covers a very broad field, only generalities applying to the operating of systems under low temperature conditions are discussed. Only in cases where gas turbine engines present specific problems have they been discussed separately.

It is true that private operations have been successful in Northern Canada for many years. It is also true that scheduled airlines operate throughout Canada during the entire year. Why, then, should the Royal Canadian Air Force maintain a Winter Experimental Establishment and why should the Ministry of Supply show such interest in it? The answer lies in the difference between military operation and civil operation. While it is possible for the bush pilot to drain the oil from the engine and take it indoors, along with his battery and other small items vulnerable to the cold, applying this procedure to a squadron of Lancasters or Lincolns would present a major problem, and for fighter aircraft which might be required at a moment's notice, it would be out of the question. The airlines are able to maintain

their schedules by using heated hangars, or at short stops where hangars are not available, they either do not shut down for more than a few minutes or they spend a long period using ground heaters to prepare their aircraft for starting.

5.2. Lubricating systems (and oil dilution).

Normally, aero-engines are designed to operate primarily on a 100-second viscosity lubricating oil. Under Arctic conditions they do so satisfactorily when used in conjunction with oil dilution, but many problems arise from the oil system installations and these are, in fact, the greatest single cause for aircraft and engine unserviceability.

During the design stage of an aero-engine, the internal oil system, because of its great importance, is very carefully thought out, but unfortunately, the remainder of the system tied up in the installation is not given the same prominence—or one gets that impression when trying to operate in the Arctic. There it seems almost as if the oil tank were pushed into any odd space available in the aircraft nearest to the engine, and its shape and size had to conform to that space. For some reason, with this set-up, the oil system seems to work reasonably well under temperate conditions, but certainly not at extreme low temperatures. We believe this is now becoming evident, especially to those operators who are concerned with aircraft which have to fly for very long periods at high altitudes, although these problems are not as complex as those involved under low temperatures at ground level.

This subject could form a paper itself but only the main fundamentals connected with low temperature operation will be discussed.

Experience has shown that the standard type of oil tank does not usually incorporate a Hotwell* of adequate size and suitable dimensions to maintain an ample amount of diluted oil and keep it segregated from the make up oil supply in the tank. Unless there is proper segregation, undiluted oil finds its way into the oil inlet, causing cavitation with possible starvation when the engine is started.

The feathering hopper,* too, needs to be in close proximity to the Hotwell, preferably surrounding and connected to it, thereby assuring that a sufficient quantity of warm diluted oil is immediately available for propeller feathering. A bleed to the feathering pump is also a necessity to avoid oil congealing in the feathering line. As an added precaution, the propellers should be partially feathered when diluting. With most standard types at present, it is found that propeller feathering cannot be accomplished for some time after take-off unless this operation is carried out, and then it is not always certain.

Oil tank shapes vary with each type of aircraft and in some instances this applies even to individual multi-engined aircraft, where the inboard and outboard oil tank shapes differ. The shape of a tank has some bearing on the rate of warm up of the make up oil, it having been proved that a tank with a narrow cross-section, where the make up oil does not extend a large distance from the Hotwell, warms up more rapidly than one with a larger cross-section. Advantage, too, should be taken to run the oil return inlet pipe in such a manner internally that the heat from the return oil assists the warming up rate. With most present types of oil tanks, the warming up rate is very slow indeed. Fig. 9 shows a slow warming up rate from a recently developed oil tank. It is also important to keep the pipe lines from the engine to the tank as short as possible and to avoid pipe lines being exposed to the slipstream.

The warm up rate of oil is an important factor for satisfactory operation. After an aircraft has been dispersed, the oil in the tank cools off (Fig. 10), the rate of chilling depending on whether or not the tank is insulated and on the chill factor prevailing at the time. After several hours the oil becomes congealed and unless some means for rapid warming up is incorporated, the oil remote from the Hotwell remains in this condition for a very long period after the aircraft has become airborne. Apart from reducing the oil supply range, lumps of congealed oil enter the tank sump with a possible risk of cavitation.

Oil tank drain fittings are another source of great inconvenience. They should be easily accessible and the drain hole should be large enough to permit rapid draining. The fitting should be designed so that the oil can be released with gloved hands and will not require the use of tools. Locking wire as a safety measure should also be avoided.

* See Appendix I.

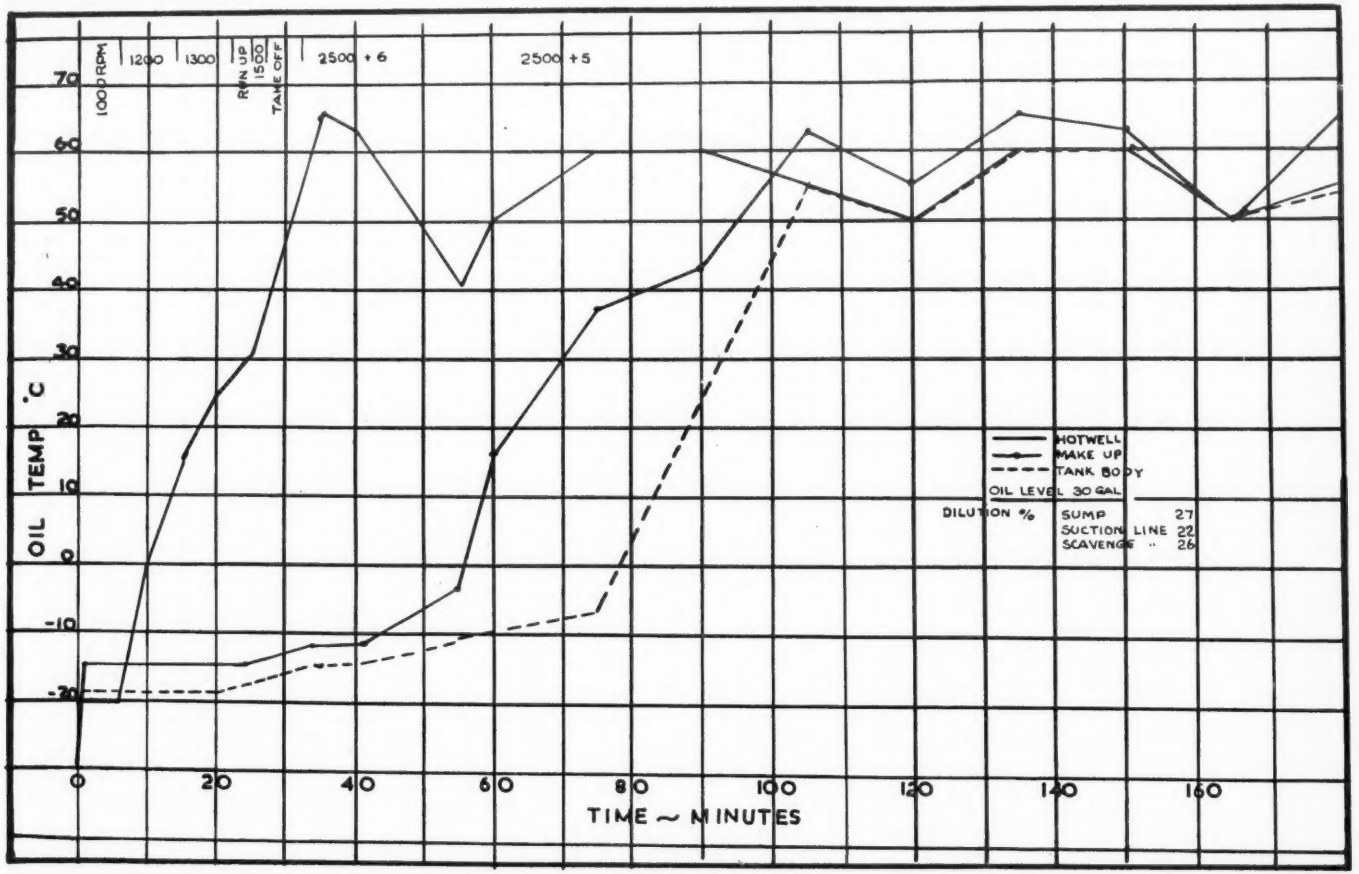


Fig. 9.
Cold start and flight warm up at O.A.T. −25°C. Merlin 621 engine.

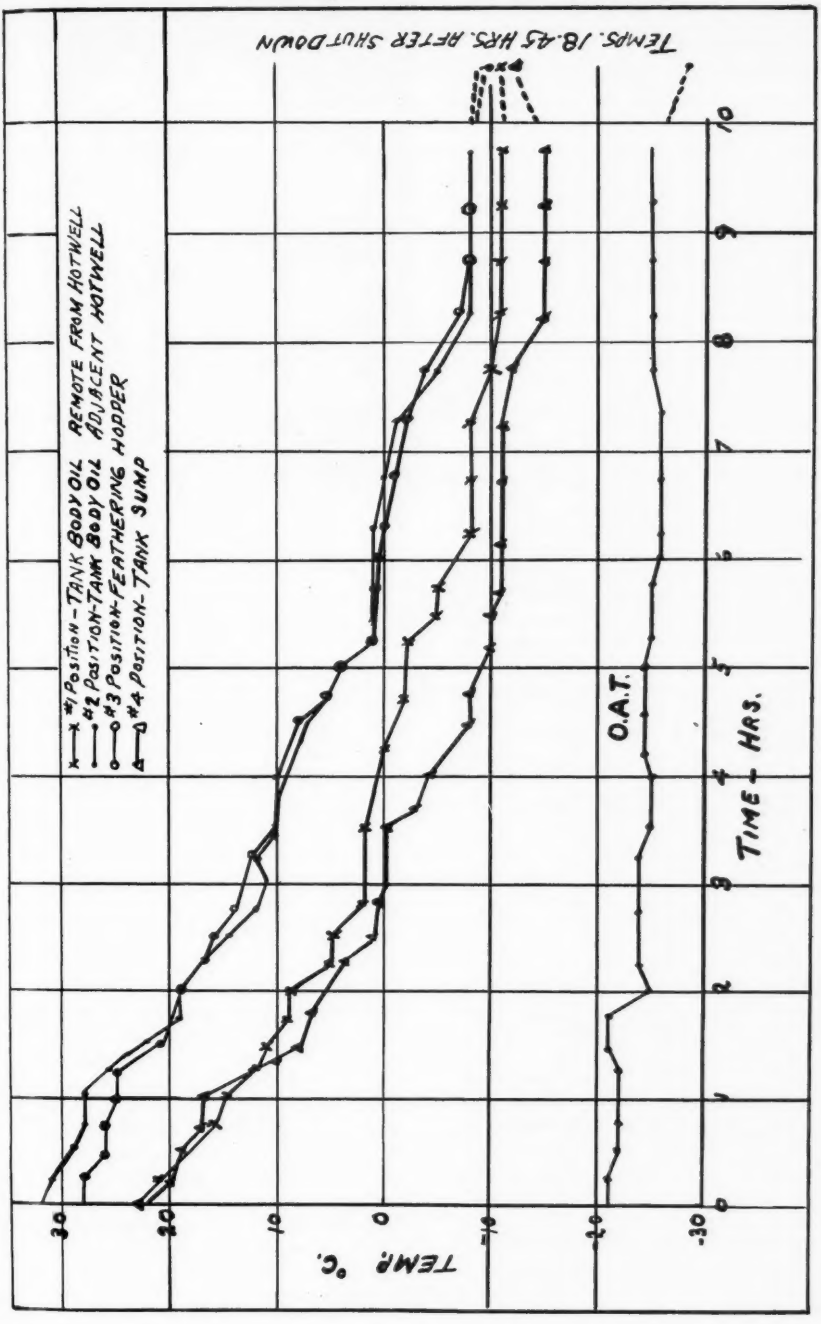


Fig. 10.
Oil chill data. North Star, Merlin 620 engine C.F. 1850.

Fig. 9.
Cold start and flight warm up at O.A.T. −25°C. Merlin 621 engine.

The filler needs to be of ample size in diameter. This is particularly necessary if an aircraft has to be replenished with oil from drums. Also, the cap should be designed to permit a simple locking and unlocking operation, bearing in mind that the operator will have to wear heavy gloves.

The layout and run of most oil tank and engine vent pipes produce breakdowns because of the trapping of condensate, which freezes and blocks up the pipe lines, causing high pressures which bulge and split the tanks (Fig. 8). Even pipe lines running in a horizontal plane, when exposed to the slip-stream will become blocked with ice, the vapour freezing and building up. For this reason, pressure relief valves in the vent lines must be located in a warm area. Lagging the pipe line has alleviated the freezing in some cases, but this is not considered good engineering practice.

Oil coolers, unless fitted with pressure relief valves to take care of sudden surge, fail with unceasing regularity. Pressure relief valves are, in fact, an essential requirement, even when the oil is diluted. Thermostatic by-pass valves are an advantage in that they give a closer control of oil temperatures over a wide range of conditions, and also prevent by-passing due to over-cooling.[2] They should, however, be set to enable diluted oil to enter the cooler at oil temperatures below 60°C. when diluting is in operation; otherwise the oil in the cooler becomes congealed or frozen after engine shut down.

Even with extensive use of dilution, oil consumptions on both liquid- and air-cooled engines are practically the same as when used under temperate conditions.

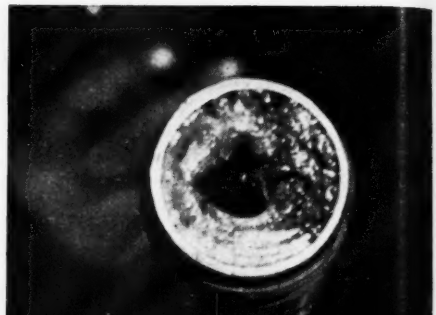


Fig. 8.
Frozen condensate oil vent pipe.

5.2.1. *Oil Dilution*

Oil dilution is an important and necessary requirement when operating aircraft under low temperature conditions and recently has become a much discussed subject. Many tests have been conducted both in the cold chamber and the field, not only in the United Kingdom, but in Canada and the United States, and considerable data has been obtained. The following are the opinions of the authors, gained from experience in the cold chamber and, in the main, from actual experience in the field.

Oil dilution is primarily intended as a means of facilitating starting of reciprocating engines under low temperature conditions by reducing the viscosity and pour point of the lubricating oil so as

(*a*) to enable the engine to be cranked at a reasonable starting speed (with the least amount of effort) and facilitate starting.

(*b*) to ensure that the lubricating oil will circulate continuously when the engine starts to run under power.

(*c*) to prevent excess pressures being imposed in the oil system pipe lines and components, and reduce the torque on accessory components and drive shafts.

(*d*) to avoid the necessity of preheating.

The system is based on the principle that within practical limits satisfactory lubrication can be obtained by cold oil thinned with aviation fuel, so long as the lubricating viscosity is preserved. In addition, an earlier take-off can be made because a satisfactory flow of lubricant to all parts of the engine is assured at almost working pressure, without waiting for normal oil temperatures to be obtained.

The fuel is introduced to some part of the oil system (usually the suction side of the oil pressure pump) and its mixing with the lubricating oil is accomplished by the oil and

fuel entering the engine oil pump and being fed inside the engine and then scavenged back to the partial circulator in the main oil tank. The diluent is eliminated by evaporation when the engine is subsequently run over a certain time period, this being dependent upon the oil system's capacity, the percentage of diluent injected into the system, and the operating temperatures of the engine. Because of the operating temperature of the bearings and the crank case structure in general, lighter ends of the fuel will tend to be driven off during the dilution process. As a result, the fuel which remains in the oil as diluent may be of a different character than that fuel which enters. Hence, lubricating mixtures containing in one case fresh fuel and in the second case an equal amount of fuel that has passed through the engine lubricating system will not have the same viscosity, although their component mixture percentages are the same.

The percentage of dilution required in an oil system depends on the O.A.T. prevailing when engine starting is required (see Fig. 11). Allowance for the amount of diluent to be put into the tank must be considered before topping up the oil tank with engine oil and obviously, the higher the percentage of dilution required, the shorter the range of the aircraft in respect to oil capacity. This disadvantage will exist until a tank has been designed which gives absolute segregation from the main make up oil.

O.A.T. °C.	Dilution %
0 to −10	10%
−10 to −20	10% to 15%
−20 to −30	15% to 25%
−30 to −40	25% to 30%
−40 to −50	30% to 35%

Fig. 11.

Samples are sometimes taken from the oil tank partial circulator in addition to the engine sump, although the latter position is usually accepted as the most suitable for data purposes.

At present there is no means of ascertaining the percentage in the system other than by sampling from the various parts of the system, and the amount of diluent injected is dependent on the r.p.m. time period, size of jet and the operating temperature of the engine during the process; once this is known, and provided that the operation is carried out with due care, a fairly accurate percentage can be estimated on the time factor. However, because of many variables with each particular engine installation, even of the same type, the same specific percentage over the same time period will not necessarily be given; therefore, for general Service use, some form of indicator in the aircraft cockpit is desirable.

As stated previously, when diluting, the lighter fractions of the fuel are driven off. During engine ground run, and as soon as the aircraft becomes airborne, boil-off takes place rather rapidly and then slows down, the time period varying with each type of engine, until the heavier fractions have lifted (see Fig. 12).

Although oil dilution has many advantages, it does accentuate the aeration already present in the oil system, which builds up in large quantities of emulsified oil, both in the crank case and tank, and normally shows its presence by venting oil from the breather when the engine is near, or at, full power. The intensity of the venting is associated with the quantity of diluent in the system and can only be brought under control by reducing power. This venting is particularly prone on in-line engines, and although various types of de-aerators have been designed, the most successful method so far encountered is that on in-line VEE engines where the crank case vent is connected to the forward ends of the camshaft covers and the vapour is released from the covers at the rear into a common pipe to atmosphere. The motion of the valves and springs, etc., appears to break up the emulsified oil, which drains back to the sump by way of the camshaft drive casings.

There are some who deprecate any form of oil dilution on the assumption that the engine life is reduced, their argument being: firstly, that at low viscosity the oil has inadequate lubricating properties and finds its way to the bearings; secondly, that the diluent washes the accumulated sludge and carbon deposits into the restricted oil ways; and, thirdly, when this deposit does find its way to the filters, they become choked. After a number of years' experience, the authors have yet to encounter this as their experience has shown that the engine is left remarkably clean and the overhaul period is lengthened. In fact, one well-known airline in North America adopts dilution procedure the whole year round for this reason. It is agreed that

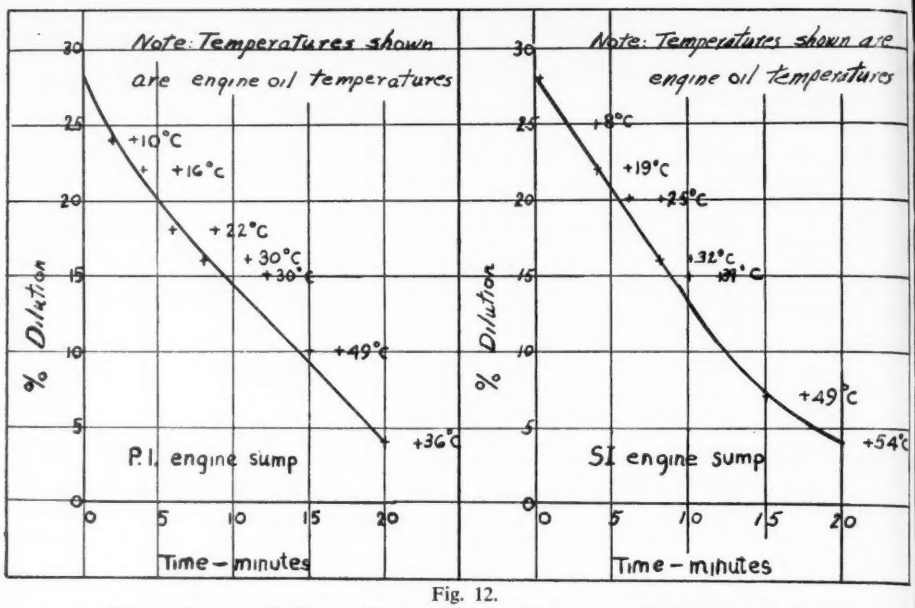


Fig. 12.
Rate of diluent boil off at 1,500 r.p.m. Merlin 620 engine on North Star aircraft.

when dilution is first used with engines that have been in service undiluted, it is essential to remove and clean the filters more frequently until it is proved that the excess carbon and sludge has been removed entirely from the internal structure of the engine. From then on it will be found that with a permanently clean engine and the absence of the usual abrasive, the overhaul periods can be increased and the condition maintained because a low viscosity oil with adequate lubricating properties finds its way to the bearings more readily than undiluted high viscosity oil at low temperatures.

After starting dilution, a drop in oil pressure is experienced, but this is not serious unless the operation requires a long period to obtain a high percentage of dilution and the oil temperature is relatively high, when the oil pressure may fall below the operating minimum (Fig. 13). This necessitates abandoning the process for a while to allow the engine to cool down, but care must be taken not to prolong this period, especially when high chill factors prevail; otherwise, congealing of the oil in the coolers will occur with consequent coring and the likelihood of cooler failure.

Finally, on no account should oil dilution be conducted in flight. With the injection of cold fuel into the inlet line of the oil pressure pump, vapour locking invariably occurs, causing loss in oil pressure to the C.S.U. with consequent over-speeding of the propellers.

5.3. Cold Starting.

5.3.1. *General.*

One of the most difficult problems associated with the operation of aircraft under Arctic conditions is engine starting. As this phase of aircraft operation is absolutely essential, it has become the limiting factor under cold weather conditions.

Military operations require that aircraft be available in the shortest time possible after a need for action has arisen and that the amount of ancillary equipment be kept to a minimum to reduce the supply problem. These requirements lead to the decision that methods of starting aero-engines should be developed which do not require pre-heating of the engines, or special equipment. This is the aim of the establishment with which the authors are connected, although some starts are made using a limited amount of heat or special starting fuel, in order to compare the advantages of these methods.

A cold start is one made after the aircraft has been exposed to the ambient air temperature for at least twelve hours without any application of external heat prior to starting. The reason for specifying twelve hours is shown on Figs. 14, 15 and 16. The data indicates the rate at which various parts of the engine cool down when exposed under winter conditions. The effect of wind on the rate of cooling is shown on Figs. 15 and 16. The rate at which the oil at the cooler inlet cools down at a wind chill factor of 2090 indicates the danger of shutting down for short periods and then starting up again, without adequate dilution in the oil system.

5.3.2. *Reciprocating engines.*

The requirement for starting aero-engines cold under winter conditions raises two major problems. These are provision for obtaining adequate cranking speed and for supplying vaporised fuel to the engine in order that the combustion will take place in the cylinders.

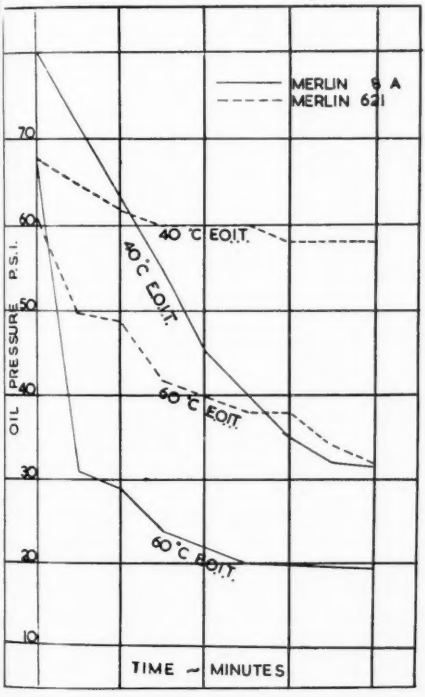


Fig. 13.
Oil pressure drop during dilution at 1,200 r.p.m.
Merlin 621 at 40°C. EOIT = 34% dilution achieved
Merlin 621 at 60°C. EOIT = 18% dilution achieved
Merlin 68A at 40°C. EOIT = 20% dilution achieved
Merlin 68A at 60°C. EOIT = 14% dilution achieved

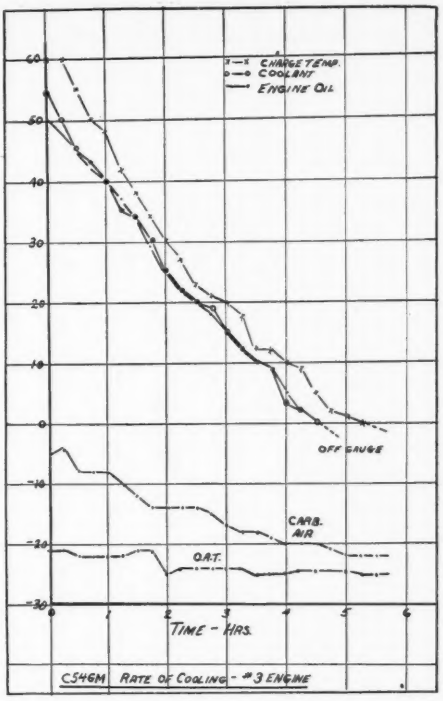


Fig. 14.
Merlin 620 engine cooling rate.

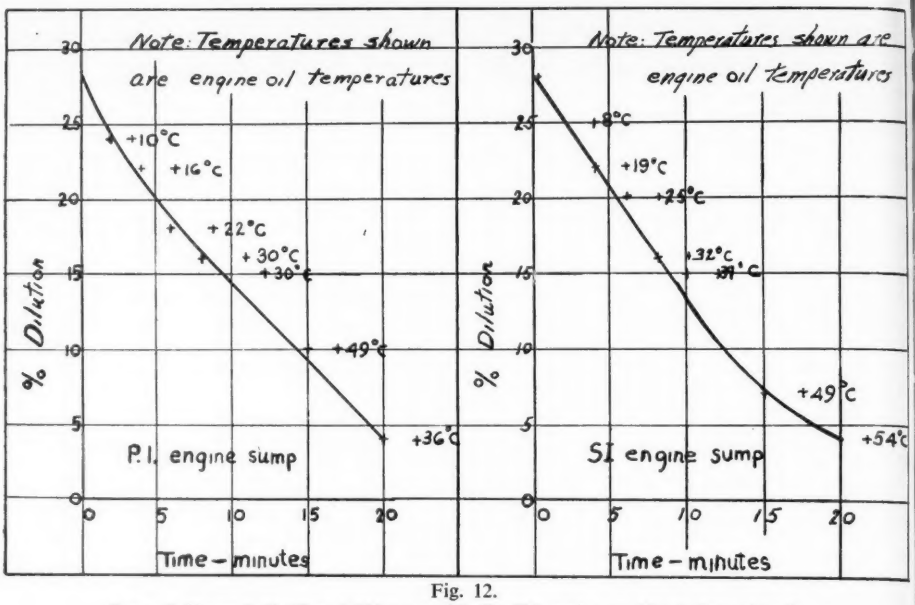
In order to obtain an adequate cranking speed, two requirements are necessary:—

(*a*) the reduction of engine friction.

(*b*) the supply of adequate power to the starter motor.

The reduction of engine friction is accomplished by the use of oil dilution. This method is well known and is used universally throughout the Service. As this topic has already been discussed, no further comments are considered necessary. Fig. 17 shows the engine torques and power required for turning a Merlin 620 engine at varying temperatures and 30 per cent. oil dilution.

The supply of electric power for engine starting presents a problem at low temperature because of the reduced accumulator capacity. This makes it impossible to use



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One of the most difficult problems associated with the operation of aircraft under Arctic conditions is engine starting. As this phase of aircraft operation is absolutely essential, it has become the limiting factor under cold weather conditions.

Military operations require that aircraft be available in the shortest time possible after a need for action has arisen and that the amount of ancillary equipment be kept to a minimum to reduce the supply problem. These requirements lead to the decision that methods of starting aero-engines should be developed which do not require pre-heating of the engines, or special equipment. This is the aim of the establishment with which the authors are connected, although some starts are made using a limited amount of heat or special starting fuel, in order to compare the advantages of these methods.

A cold start is one made after the aircraft has been exposed to the ambient air temperature for at least twelve hours without any application of external heat prior to starting. The reason for specifying twelve hours is shown on Figs. 14, 15 and 16. The data indicates the rate at which various parts of the engine cool down when exposed under winter conditions. The effect of wind on the rate of cooling is shown on Figs. 15 and 16. The rate at which the oil at the cooler inlet cools down at a wind chill factor of 2090 indicates the danger of shutting down for short periods and then starting up again, without adequate dilution in the oil system.

5.3.2. *Reciprocating engines.*

The requirement for starting aero-engines cold under winter conditions raises two major problems. These are provision for obtaining adequate cranking speed and for supplying vaporised fuel to the engine in order that the combustion will take place in the cylinders.

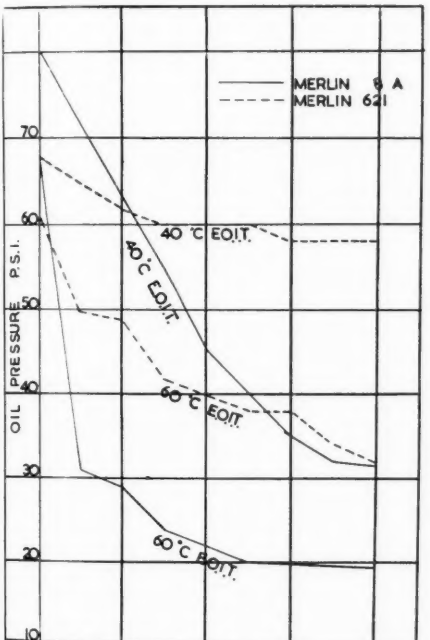

Fig. 13.
Oil pressure drop during dilution at 1,200 r.p.m.
Merlin 621 at 40°C. EOIT = 34% dilution achieved
Merlin 621 at 60°C. EOIT = 18% dilution achieved
Merlin 68A at 40°C. EOIT = 20% dilution achieved
Merlin 68A at 60°C. EOIT = 14% dilution achieved

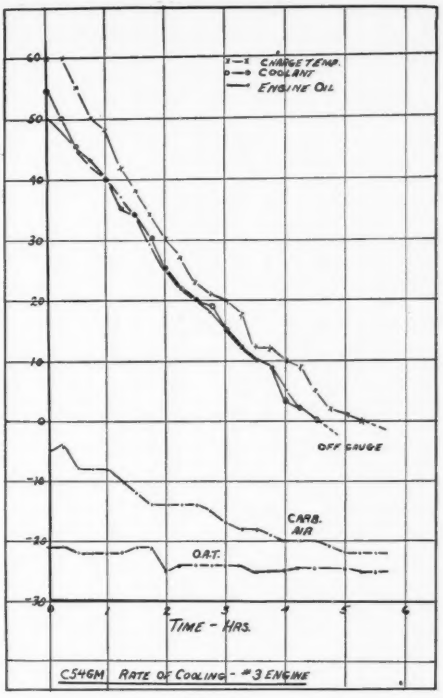

Fig. 14.
Merlin 620 engine cooling rate.

In order to obtain an adequate cranking speed, two requirements are necessary:—

(*a*) the reduction of engine friction.

(*b*) the supply of adequate power to the starter motor.

The reduction of engine friction is accomplished by the use of oil dilution. This method is well known and is used universally throughout the Service. As this topic has already been discussed, no further comments are considered necessary. Fig. 17 shows the engine torques and power required for turning a Merlin 620 engine at varying temperatures and 30 per cent. oil dilution.

The supply of electric power for engine starting presents a problem at low temperature because of the reduced accumulator capacity. This makes it impossible to use

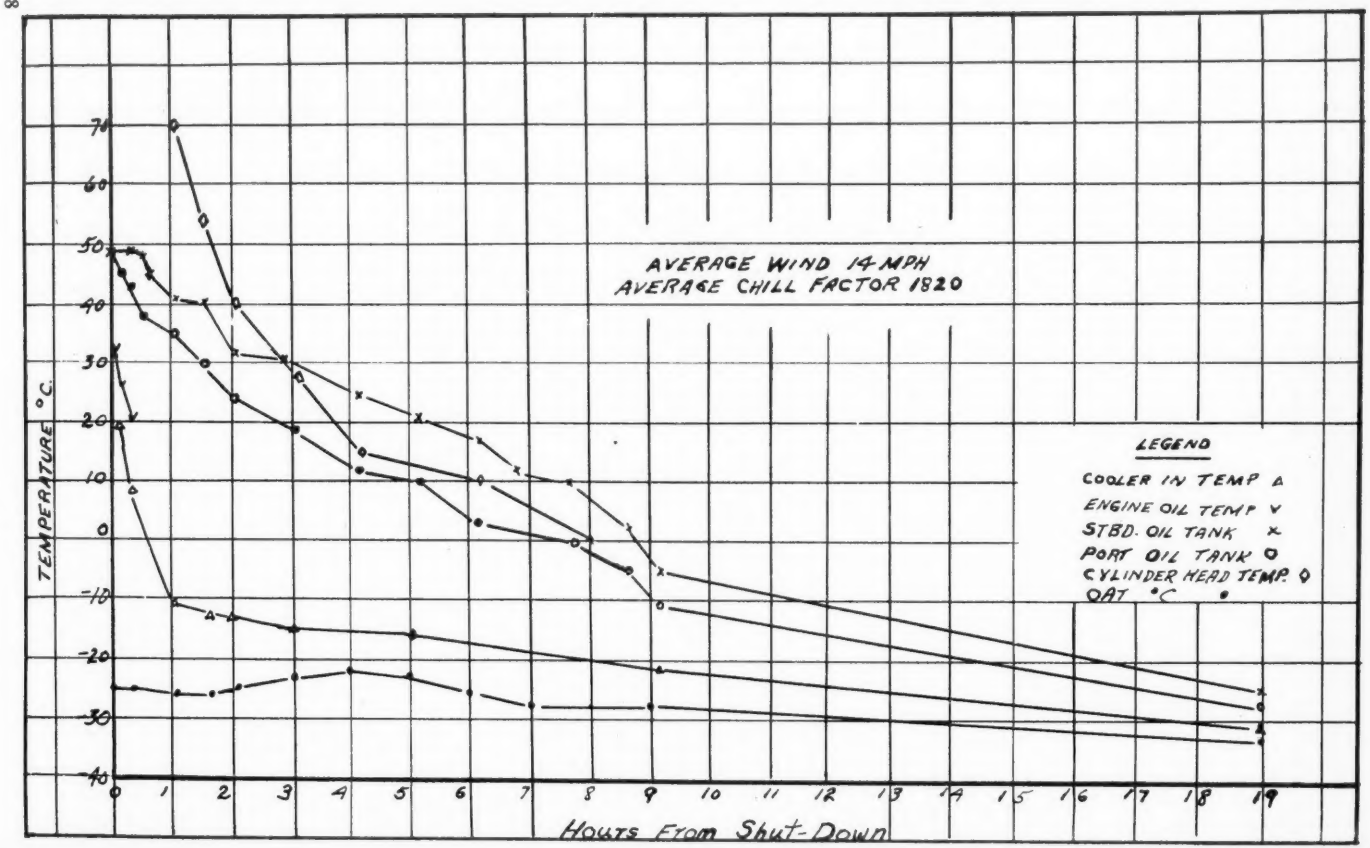

Fig. 15.
P. & W. R.1830-92 engine. Rate of cooling at CF.1820.

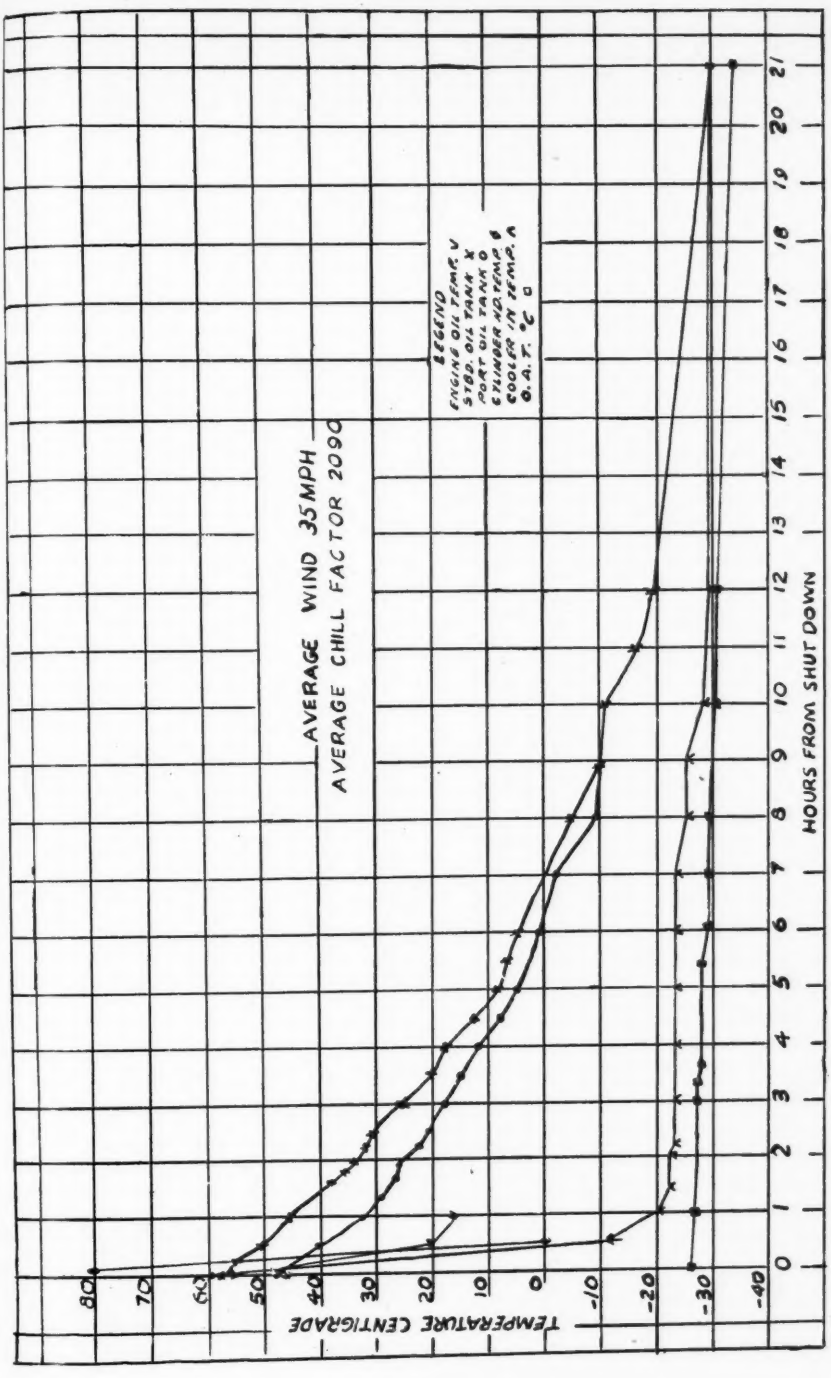

Fig. 16.
P. & W. R.1830-92 engine. Rate of cooling at CF.2090.

the aircraft accumulator for starting purposes. The present procedure is to use an accumulator trolley with a small petrol electrical set to keep the accumulators charged. Even with this system the accumulators in the trolley must still be kept warm, either by continuous charging or by providing heated storage for the trolleys when not in use. Limited experience with petrol electric sets without accumulators has proved encouraging and it is thought that this system may prove the most satisfactory for engine starting.

Although a determination of the minimum cranking speed at which starts can be obtained is difficult, results of tests have indicated that 25 r.p.m. is the minimum crank shaft speed at which starts are normally accomplished.

The next and most important factor in starting aero-engines at low temperatures is the priming. During past years the lowest temperatures at which engines could be started has depended upon the ability of the priming system to vaporise the fuel going to the cylinders. A satisfactory priming system must accomplish the following things:

(*a*) vaporise the priming fuel sufficiently so that combustion will take place in the cylinders, and

(*b*) supply sufficient fuel to the cylinders after the initial firing to allow the engine to pick up and run smoothly on its main fuel system.

The factors governing the first item are many and are so involved that a full treatment of the problem is beyond the scope of this Paper. The main factors governing the vaporisation and distribution of the fuel to the cylinders are as follows:—

(*a*) type of jets

(*b*) fuel pressure

(*c*) configuration of induction systems

(*d*) location of jets

(*e*) type of fuel.

Many types of priming jets are available, but the type that has proved most satisfactory is that developed by the R.A.E. and used extensively on Roll-Royce engines. In this jet the fuel enters a cylindrical chamber tangentially and is forced out through orifices located on the axis of the cylinder. This causes the fuel to leave the jet in a conical spray, the angle of the cone and rate of flow being dependent on the fuel pressure.

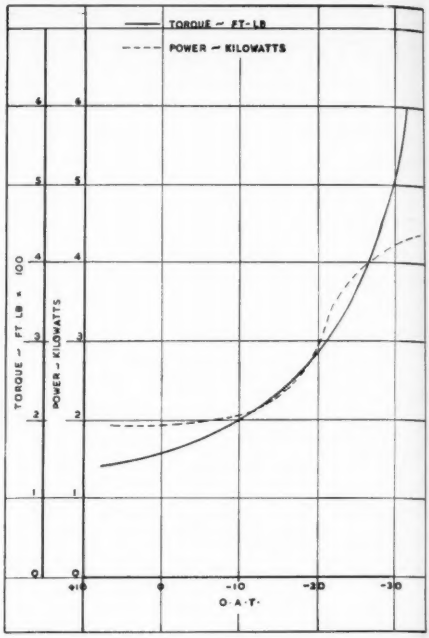

Fig. 17.
Torque and power required for Merlin 620 at varying O.A.T. 30 per cent. dilution.

It has been found that the priming pressure has a great effect on the vaporisation of the fuel. The standard Ki-gass priming system operates at a relatively high pressure, but delivers fuel too slowly for satisfactory results. This leads to the difficulty that at low temperatures the priming fuel condenses in the cold intake manifold and cylinders before sufficient fuel can be supplied for cold starting. A second shortcoming of this system is the fact that even with extreme exertion it may be impossible for the operator to keep the engine running in the event of a slow pick up.

Electric priming using normal fuel pressure, approximately 15 psi, has the advantage that it supplies a continuous flow of priming fuel with no physical exertion by the operator. This system proved satisfactory for engine starting at temperatures down to – 25°C., and below this temperature insufficient vaporisation of the fuel appeared to be the limiting factor. In order to improve the starting performance, the priming pressure was increased to approxi-

mately 75 psi. This resulted in improved starting performances and cold starts now can generally be accomplished down to -35°C. Data at lower temperatures than this is uncertain because of the limited experience at these temperatures, but cold starts have been made on several occasions below -40°C.

The configuration of the induction system and the location of the priming jets has a great effect on the efficiency of the priming system. The priming jets on most in-line engines are located in the intake manifold supplying fuel to all cylinders. This system has given the most satisfactory performance. Some radial engines are primed in the intake manifold trunks, and fuel is supplied to only the top cylinders. This is done to avoid the danger of trouble in the lower cylinders due to over-priming (or flooding with petrol or oil). This system has not given good starting results at low temperatures as it is impossible to get all cylinders to fire.

A modified priming system was tried on the Pratt and Whitney R.1830-92 engine in a Dakota aircraft, introducing the priming fuel into the impeller inlet. This system did not prove satisfactory as the fuel impinged on the walls and condensed and ran out of the supercharger drain. Two new systems are under consideration for this engine, the first involving the design of new jets of the R.A.E. type giving better atomisation at the impeller inlet, the second to inject fuel at the inlet valve of each cylinder.

The final factor in engine priming is the fuel. A number of tests have been made using high volatile priming fuel with the following characteristics:—

Specific gravity	.632
I.B.P.	24.4°C.
10 per cent. B.P.	26.7°C.
50 per cent. B.P.	40.0°C.
90 per cent. B.P.	71.1°C.
F.B.P.	74.4°C.

Good starting was achieved with this fuel at approximately ten degrees centigrade below that at which good starts could be achieved with 100 octane fuel.

The desirability of eliminating any extra supply problems has led to further attempts to improve the starting performance with 100 octane fuel; and with the use of high priming pressures, as outlined previously, it appears that high volatile fuel may be unnecessary for the majority of conditions encountered in the Canadian Arctic.

Briefly, the present status of the cold starting of reciprocating engines is that in-line engines can be started consistently down to -35°C. with 100 octane priming fuel and, on occasions, have been started as low as -50°C. The radial engines have not been as satisfactory and it is considered that more development work is necessary on the priming systems before they can be considered satisfactory for Arctic operation.

5.3.3. *Gas turbine engines.*

Gas turbine engines are much easier to start at low temperatures. This is attributed to the following factors:—

(*a*) The lubricants used are less viscous than those for reciprocating engines.

(*b*) There are fewer moving parts and consequently much less engine friction.

(*c*) The initial rate of light-up is less critical because of the continuous combustion.

Experience with the Derwent and Goblin engines has proved very satisfactory, both engines starting readily below -45°C. The Goblin at present is limited to -35°C., as it uses the more viscous oil, DED. 2480.

The U.S.A.F. at Ladd Field in Alaska has used gasoline as an alternative to kerosene to obtain better starting performance. Although we have made provision for this, the need has not yet arisen.

5.4. STARTER SYSTEMS.

A comparison of the three types of starter systems, electric direct cranking, electric inertia and direct cranking, and cartridge type, shows the following advantages and disadvantages for each type in winter operation.

The electric direct cranking gives a sufficient number of revolutions to allow the engine to pick up; but it requires a source of electric power, entailing accumulator trolleys which add to the maintenance and supply problems, and it has a high peak load just as it is overcoming the engine's static friction.

The electric inertia and direct cranking has the same characteristics as the direct cranking, except that as its inertia overcomes the static friction, the peak load is not as high.

The cartridge starter has the minimum supply requirements, but may need more maintenance if the starting requirements are heavy. It has the serious disadvantage that

it only produces a few revolutions and does not assist distribution of the priming fuel, and if the engine does not pick up at once, starting is difficult.

5.5. Induction systems.

5.5.1. *Reciprocating engines.*

Low outside air temperatures have little effect on the functioning of induction systems. The only precaution necessary is to ensure that blowing snow does not block the system during dispersal or when taxi-ing through loose powdery snow. On some aircraft it has been found necessary to taxi with the induction system in the hot air position to keep the charge temperatures within the engine operating limits. Failure to do this causes the plugs to load up with subsequent rough running and on occasion has prevented take-off. Aircraft fitted with inter-coolers have been found to give low charge temperature at low O.A.T.s with consequent rough engine running. The introduction of a Thrustat oil control valve into the inter-cooler system, opening at 55°C. and fully open at 75°C. produced satisfactory engine operation.

A few isolated tests have indicated that improved fuel consumption may be obtained by the use of hot air during flight. As this was noticed on aircraft fitted with inter-coolers which maintained a constant charge temperature, it was attributed to the fact that the warm air gave better vaporisation of the fuel in the carburettor. The decrease in fuel consumption noted was as high as 10 per cent. increase in A.M.P.G.

5.6. Ignition systems.

Ignition systems have generally proved satisfactory during winter operations. On only one aircraft has this system proved a limiting factor for cold weather operation. In this case, it was found that condensation caused a breakdown of the insulation in the booster coils and starts below – 35°C. could only be achieved with application of heat to the booster coils. This is considered a minor design point of the particular coil.

The performance of spark plugs varies with the type of engine and they do not offer any more trouble under winter conditions than under temperate conditions. On engines without controlled charge temperatures, it was found necessary to change the plugs slightly more often than during temperate operation.

5.7. Fuel systems.

5.7.1. *Reciprocating engines.*

Some difficulties have been encountered with fuel systems during winter operations. Normal fuel tanks have caused no trouble but integral tanks have a tendency to leak at low temperatures, particularly when the aircraft is moved in and out of heated hangars. Leaks occur around the rivets and are caused by expansion and contraction of the tanks, which breaks up the sealing compound.

Certain types of flexible hose have proved unsatisfactory as they have either shrunk or become rigid at low temperatures. The best solution to this problem is the selection of fuel lines which do not do either of these things. If lines are subject to shrinkage, extra length must be provided to allow for contraction or, if they become brittle at low temperatures, care must be taken not to move them while in this condition.

Difficulties encountered with leaks around moving shafts in pumps and selector valves can largely be overcome by the use of materials which retain their sealing properties at low temperatures.

The most critical factor in the fuel system for winter operation is the method of injecting the fuel into the engine. Only two systems have been tested, the standard carburettor system and the fuel injection system which injects fuel into the air stream just ahead of the supercharger. The carburettor systems have operated satisfactorily, but the fuel injection systems have not performed very well at low temperatures.

Several of the engines used during the past season were equipped with fuel injection pumps of the Rolls-Royce or S.U. design. Considerable difficulties were encountered with the pumps in having the engine pick up after the initial firing. On engines equipped with electric starters, starting was not difficult, but it was necessary to let the engines idle at higher speeds than normal to obtain smooth running.

When used in conjunction with a cartridge starter it was necessary to prime for prolonged periods before the engine would run smoothly on its own fuel system.

It is considered that some method of improving the slow running performance at low temperatures is necessary before these systems can be considered satisfactory for winter operation.

5.7.2. *Gas turbines.*

Only one component in the fuel system on each of the gas turbine engines has failed during winter tests. In the case of the Derwent engine, the diaphragm in the accumulator trip valve failed, allowing fuel to leak, but the fuel leak was noticed before it was sufficient to affect engine starting. On the Goblin engine the diaphragm in the starting valve became stiff at lower temperatures and would not allow the accumulator to discharge fuel to the engine during the starting cycle. This fault was corrected by local application of heat.

Both of the above faults are of a minor nature which can be rectified by the choice of a proper material which is not affected by low temperatures.

Slushing of the fuel has not been experienced at any time, although the aircraft have been exposed to ground temperatures as low as $-50°C.$; neither has ice formation been evident in the aircraft fuel system. This latter is attributed chiefly to

(*a*) Strict use of the "streamline filter" on every refuelling occasion.

(*b*) Maintaining full fuel tanks while on the ground.

(*c*) Avoiding placing the aircraft into heated hangars after low temperature exposure.

5.8. COOLING SYSTEMS.

Both liquid- and air-cooled engines have proved satisfactory for winter operation. On some occasions it has been necessary to fit blanks to the radiators or baffles to the cylinders to maintain operating temperatures. However, with installations designed for operation at high altitudes, the standard radiator shutter or cowling gills give adequate control for winter operation. A coolant mixture of 60 per cent. glycol and 40 per cent. water is used in the coolant systems and slushing of this mixture has not been experienced.

Rubber coolant joints tend to leak after entering the cold temperature zone but disappear when the clips are tightened.

5.9. ENGINE ACCESSORIES.

As this subject is too broad to be covered in detail, only features common to all accessories will be mentioned.

The greatest problem with accessories is proper lubrication. Where they are lubricated indirectly by engine oil, there is a danger of oil congealing in the units while the engine is stopped, causing failure of the drive when starting again. In some cases this has been remedied by introducing dilution to the accessory.

When the engine is fitted with an auxiliary gear box, it is advisable to use a less viscous oil for the accessories. The general practice has been to use oil to Specification D.T.D. 44D., which has proved satisfactory.

Another difficulty which has been encountered with accessories is the combined use of dissimilar metals for bearings and moving parts, which gives rise to seizure or excessive play under low temperature conditions.

5.10. PROPELLERS.

No serious difficulties have been encountered in normal propeller operation. While constant speed units are sluggish when engines are first started at low temperatures, their action is normal once the engine oil has warmed.

The main problems associated with propellers at low temperatures is the operation of the feathering system. As the supply of feathering oil has been discussed in Section 5.2, nothing further will be added, except to stress the need for an adequate supply of warm diluted feathering oil.

Most systems are at present fitted with a bleed, which allows a small quantity of engine oil to circulate through the feathering systems to warm up the oil in the feathering line and to prevent the oil in the lines from congealing during flight. Together with the above items, it is essential that the feathering lines be kept as short as possible.

One system which appears to offer great advantages for winter operation is a propeller designed in the U.S.A. This has its constant speed and feathering system entirely contained in the hub and uses hydraulic fluid as an operating medium, thus eliminating any trouble caused by congealing oil.

Wooden or synthetic blades in metal adaptors are greatly affected when used in areas of extreme low temperature. Because of the differential expansion, the blades become dangerously loose at the root and the action of applied heat prior to flight acts only as a palliative.

PART III. MAINTENANCE

6. AIRCRAFT ENGINES AND EQUIPMENTS.

6.1. GENERAL.

As has been discussed in Section 2, the effect of cold on personnel is one of the major items in the servicing of aircraft under Arctic conditions. Only by the supply of adequate clothing and equipment can an operation under Arctic winter conditions be a success. The following sections outline special procedures required for servicing in the outdoors under Arctic conditions, and some of the special equipment necessary.

Care should be taken to protect the vulnerable parts of the aircraft from the elements when dispersed under winter conditions. It is recommended that, once an aircraft has been prepared for winter operation, it be placed in a heated hangar only in cases of absolute necessity. Extreme changes in temperature cause countless defects, some of which are fluid leakage due to contraction and expansion of the seals and variations in reservoir pressure.

The increase in time required to accomplish various tasks under dispersal conditions varies greatly with the individual. An approximate guide of the time required for certain servicing operations is as follows:—

(*a*) Daily inspections require 50 per cent. to 100 per cent. longer, depending on the size of the aircraft.

(*b*) Minor inspections require 100 per cent. to 500 per cent. longer, depending on the size of the aircraft and conditions at time of inspection.

These figures are to be considered only as a rough approximation, as tests made on the servicing of individual aircraft by experienced personnel cannot be expected to give an accurate picture of squadron servicing.

6.2. AIRFRAME.

The following points should be observed when servicing airframes under winter conditions:—

(*a*) *Lubrication*: All points should be carefully cleaned and re-greased with winter lubricants.

(*b*) *Controls*: Cables should be re-tensioned for the mean operating temperature.

(*c*) *Hydraulic systems*: Leaks can be minimised if large changes in temperature are avoided. If an aircraft is being brought into a heated hangar ensure that selectors are in selected position so that fluid is not trapped in lines.

(*d*) *Pneumatic systems*:

i. Use dry air for recharging. If there is uncertainty of the state of the air, check the methanol container after recharging.

ii. Apply heat when draining oil and water traps to ensure that no congealed oil or frozen water remains in the traps.

iii. Avoid leaving pneumatic parking brakes on during cold weather, as this causes a loss of pressure, and allows the brakes to stiffen in the "on" position.

iv. A soap and glycol-water solution (60 per cent. glycol, 40 per cent. water) may be used for tracing air leaks at low temperatures.

(*e*) *Undercarriage*:

i. Care should be taken to use dry air when recharging oleo legs.

ii. Oleo legs and tyres should be charged to give the proper extension and pressure at the mean operating temperature.

iii. Ensure that all particles of snow and ice are removed from hydraulic jacks, oleo struts, etc. and that these parts are smeared with a low freezing oil.

6.3. ENGINES.

The following points should be observed when servicing engines under winter conditions:—

(*a*) *Lubrication*:

i. A heated oil dispenser is necessary for operation during winter conditions.

ii. Topping up the oil system, when dilution is used, should be done at the following times: if the engine is diluted at high oil temperatures prior to shut down, topping up should not be done until just prior

to the next start, or, if it is necessary to allow the engine to cool before diluting, topping up may be carried out immediately after shut down, while waiting for the engine to cool.

(*b*) *Ignition systems*:

i. If charge temperatures are low more frequent inspection of the spark plugs may be necessary.

(*c*) *Starter systems*:

i. Particular care must be taken to follow the operating instructions laid down for each type of starter. (As more attempts at starting are likely, the starter should be allowed to cool in between starts.)

ii. More frequent inspection of the starters is desirable, particularly the mechanical components.

(*d*) *Fuel systems*:

i. Care must be taken to separate all water from aviation kerosene. The use of a streamline filter is absolutely essential at all times.

ii. Float - type water segregators designed for petrol will not function with kerosene because of its different specific gravity.

(*e*) *Coolant systems*:

i. As pure glycol freezes at – 10°C., it is preferable to mix the glycol with water before shipping to an advanced base.

6.4. Ground Handling Equipment.

Under normal operating conditions, ground handling equipment is invariably treated as of secondary importance, consideration often being given to improvisation. Under Arctic conditions it has been found that suitable ground equipment is of paramount importance, insofar that without it aircraft of any number cannot operate on an organised basis. The main items under this category can be classified as follows:—

(*a*) *Ground heaters*: Although emphasis has been placed on starting engines cold and operating with the least amount of subsidiary aid as possible, there are occasions, especially with present type of design aircraft, when items of ground equipment have to be used to avoid a breakdown of continuity, and the ground heater is one of these essential pieces. Apart from providing heat when necessary for engine starting, it has other uses of great importance. For instance, it is necessary to apply heat to the mechanic's hands when he is engaged on work of an intricate nature and cannot wear gloves. Again, heat may be necessary to raise the temperature of the aircraft or ground starter batteries. Pneumatic services may not hold air until heat has been applied on the affected parts. Instruments, particularly compasses, may have to be heated before flight, and so on. In fact, there are scores of uses to which this equipment may have to be applied. The type of heater most useful for these purposes should be capable of producing at least 250,000 B.Th.U. and, if operated by an internal combustion engine, should be easy to start, preferably electrically or kick-starter fashion, and be easy to maintain. It needs to be light, compact, robust, be mobile over snow and of a size suitable for transport by air. It should have at least three heater ducts, the extensions being made of material suitably flexible to withstand cold weather conditions and not prone to deterioration at high temperatures, especially at the inlet end. The most common type in use to-day is the Herman-Nelson heater shown in Fig. 18.

(*b*) *Ground starter units*: This item of equipment is a most important adjunct to aircraft operation and under Arctic conditions is practically indispensable. The standard types now in use with the Service have several drawbacks, one of which is that unless continually on charge, the batteries lose their capacity at low temperatures. This necessitates more attention and maintenance to avoid freezing of the electrolyte and would probably be diminished by using the alkaline type of battery which has been found to deteriorate at a much slower rate than the lead acid type down to about – 30°C., and as the case and plates are more robust, burst and cracked containers would be avoided at extreme lower temperatures. The cables, being covered with synthetic rubber become brittle and break off, exposing the naked cable, unless special care is taken when handling. As the charging engine is exposed to atmosphere, it

Fig. 18.
Herman-Nelson ground heater, 250,000 B.Th.U.

requires screening, otherwise at high chill factors it becomes inoperative.

Petrol electric sets are considered better suited for starting multi-engined aircraft, as more power is available throughout the stage.

(*c*) *Air compressors*: Experience has shown that the power unit will not normally operate the standard type of compressor unless it is disengaged initially and run for a warming up period. With very high pressure units, this would become worse and calls for a clutch mechanism in the drive. Some form of air dryer is also required on the compressor unit to eliminate condensate entering the aircraft services.

(*d*) *Hydraulic jacking equipment*: The standard jacking equipment is found to operate satisfactorily under low temperature conditions. They mostly employ leather glands and seals internally. To enable the jacks to be transported by air they should be designed to break down into small components and be lighter in weight. For mobility on the ground, ski attachment feet are also an advantage.

(*e*) *Oil bowsers or dispensers*: Refuelling aircraft with engine lubricating oil at advanced or remote places under Arctic conditions is quite a problem with the present type of standard equipment available. A great deal of thought and empirical development is necessary with this type of equipment to find the most suitable for the task, which will depend on the mode of operation to be undertaken. When refuelling from drums and/or bowser, some form of adequate heat, either hot air or electro-thermal, is necessary to decongeal the oil and enable rapid refuelling. Experience has been obtained with a lightly constructed mobile frame fitted with a semi-rotary hand pump. The drum of oil located on the frame is enclosed, complete with pump and lines, under a canvas canopy which has a fitting whereby a heater duct can be connected. This attempt, although decongealing the oil to a certain extent, was found to be slow and laborious.

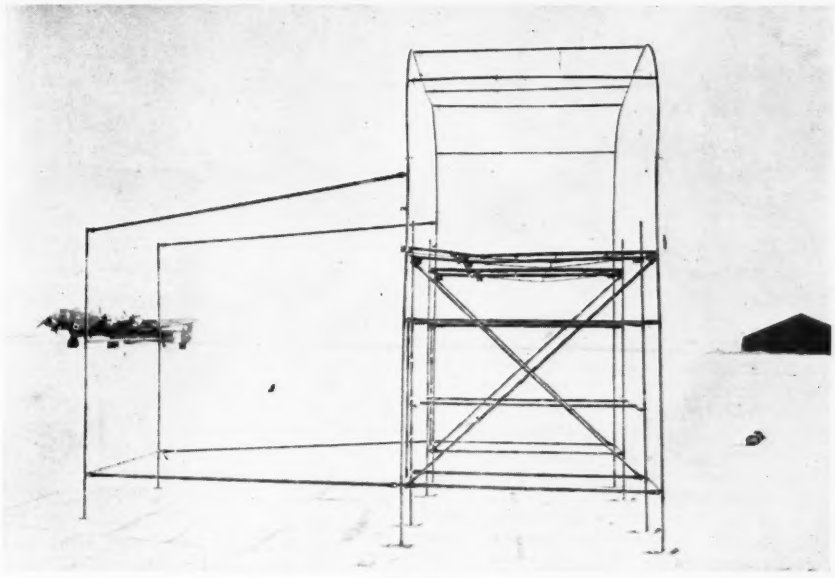

Fig. 19.

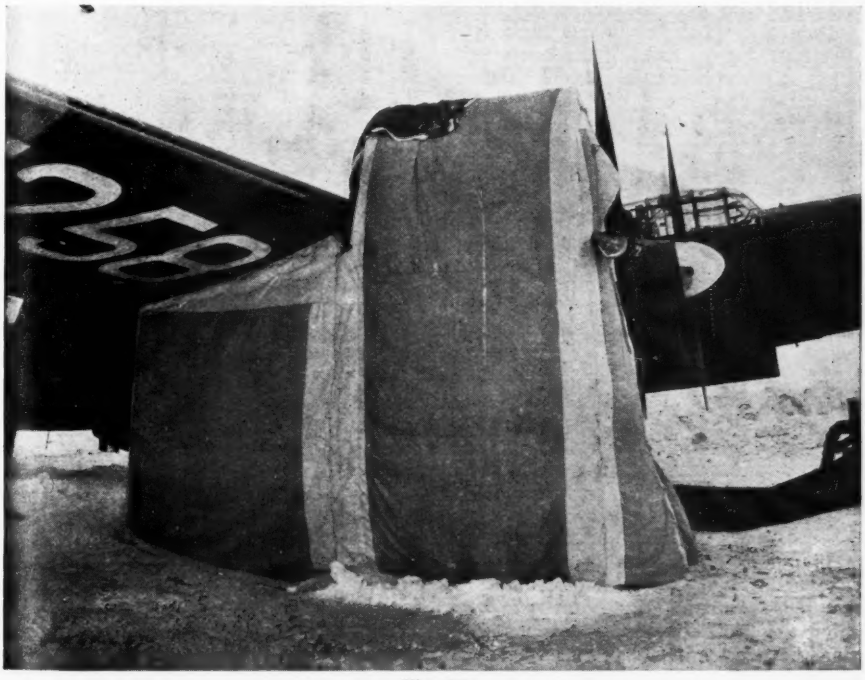

Fig. 20.
Engine tent with wheel well extension.

Fig. 21.
Engine inspection stand with canopy.

(*f*) *Aircraft inspection stands*: This is not a great problem with small aircraft types, provided that skis are fitted to the stands which incorporate retractable spikes for gripping snow or icy surfaces when in use. The platform should be of heavy gauge mesh steel to enable the oil to drain away and also to act as a foot-scraper for the soles of the boots worn by the servicing personnel, thereby ensuring good foot-hold. For inspection stands for large and multi-engined aircraft, provision is necessary for fitting a canopy or shelter tent to protect the ground crew and if needs be, to allow heat to be applied internally. This type of stand should be light and robust and easily broken down for air transport (Figs. 19, 20 and 21).

(*g*) *Walkways*: Canvas baton walkways, as shown in Fig. 22, are desirable for the safety of personnel and the protection of the aircraft surfaces.

PART IV

7. CONCLUSIONS.

A.P. 970, S. & T.M. No. 4/48 and the appropriate D.T.D. specifications outline broadly the requirements which are necessary to enable aircraft to operate in Arctic regions. In this Paper we have endeavoured to illustrate the shortcomings encountered from a practical viewpoint when operating one of a type among several aircraft with a team of personnel, some of whom have cold weather experience. From this one can appreciate the magnitude and ramifications involved if successful operation is to be attained with large numbers of aircraft with personnel not having cold weather experience, and can forecast the results if an attempt were made without first applying the requirements and taking the necessary precautions.

Much headway has been made over the past few years, particularly on the main function of engine starting and, in fact, a few years ago where consistent engine starting more often with the application of heat at an O.A.T. of $-25°C$. was considered favourable, consistent cold starts at an O.A.T. of $-35°C$. are to-day considered a normal event with reciprocating engines. Gas turbine aircraft present no problem at all down to $-45°C$., particularly those incorporating torch ignitors. To improve on the starting technique of reciprocating engines will necessitate the development of higher priming pressures, better atomisation and easier cranking with oil dilution.[3]

Although much progress has been made to enable hydraulic components and oleo shock struts to operate, further development is necessary to ensure longer periods of serviceability. It is surprising that hydraulic jacking equipment stands up to the rigours of cold weather and it is no doubt because the seals

and glands are made from leather. This material should be explored for use in aircraft hydraulic services also.

As propeller feathering is problematic with the present type of system, especially immediately after take-off, some consideration should be given to divorcing the feathering system entirely from the main engine oil system. It is visualised that, having a separate tank of adequate dimensions and using a very low freezing fluid, feathering could be accomplished at any required time. As there is always a special reason for stopping the engine, contamination of the engine and lubricating systems would not arise.

It would be opportune at this stage to mention that over a period of three years, the turbine blades of jet engines have not shown signs of failure due to the stresses when starting up from cold.[4] This in spite of being soaked for many hours down to almost -50°C. and subjected to the rapid change of temperature when simulating "scrambled take-offs." At first, this possibility was the cause for frequent inspections during test periods and although these have been relaxed somewhat, they are still maintained with regularity.

Little progress has been made with winter clothing, which should be light in weight, warm, loose and not cumbersome. The present type of clothing tends to be heavy and most cumbersome, which restricts the movement of personnel, especially those who maintain the aircraft. Intensive research and development is necessary with this type of equipment to ensure maintaining a high level of morale among operating personnel.

Reverting to the first paragraph of this section, it might be construed that equipped bases with heated hangars and the like would have to be an essential requirement to operate large fleets of aircraft successfully. The provision of such is impracticable but a material aid to this might be accomplished by supporting squadrons, etc. with "parent aircraft."

These aircraft could incorporate an auxiliary power unit of sufficient capacity to operate a heater unit of some 400,000 B. Th.U., A.C. and D.C. generator sets, compressor and hydraulic pump. These components would not only serve the purpose for servicing the aircraft but the parent aircraft could also act as a radio and navigational station. In addition, a small repair workshop and medical station could be installed. If the aircraft chosen for this type of duty were not large enough to accommodate these services, a glider could be used in conjunction with it, equipped, for instance, as the radio and

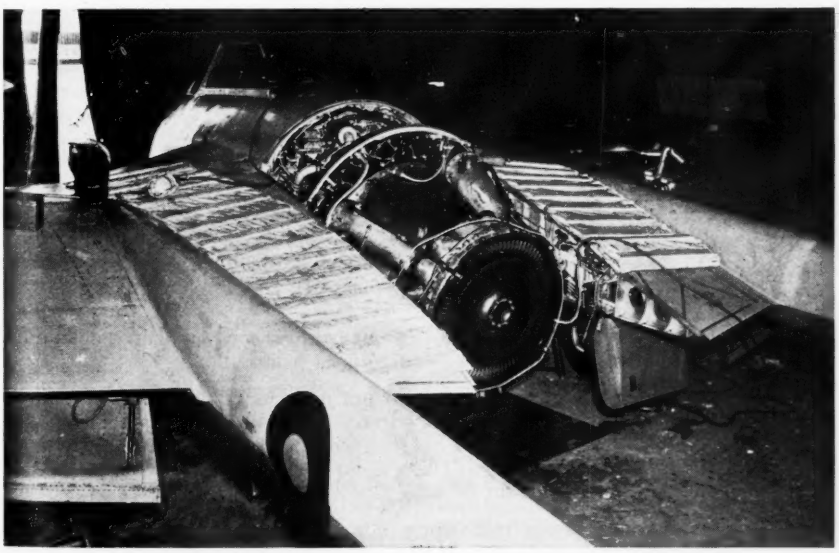

Fig. 22.
Typical servicing walkways.

navigational station. This idea could be modified and enlarged upon according to the operational requirements.

It is considered that the helicopter would also serve an important role in Arctic operations.. Apart from rescue work and observation duties, it would be valuable for surveying frozen lakes and potential advance bases. Experience on the functioning of this type under low temperatures has yet to be gained.

Although the opinions expressed in this Paper are not necessarily those of the Ministry of Supply and the Royal Canadian Air Force, the authors wish to acknowledge their indebtedness to them for permission to present this Paper. Grateful thanks are also due to many of the staff of the Winter Experimental Establishment and the Mechanical Engineering Division of the National Research Council who have been associated with this work.

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APPENDIX I.

Definitions.

Oil dilution system:	The mechanism by which diluent is added to the lubricating system in order to reduce the viscosity and pour point of the lubricating oil.
Diluent:	A fluid, usually petrol, which reduces the viscosity and pour point of an engine's lubricant.
Mixture (dilution):	The mixture of the engine lubricating oil and diluent.
Per cent. of dilution:	The amount of diluent in the mixture expressed in whole numbers, *i.e.* a mixture consisting of twenty parts of diluent and eighty parts of oil by volume is a twenty per cent. mixture and its dilution shall be known as twenty per cent. Percentage of dilution shall not be measured as the amount of diluent with respect to the original amount of oil.
Boil off:	The distillation or evaporation of the diluent.
Temperature Terms:	When an expression of below $-30°C.$ is made, it indicates that the temperature is colder than $-30°C.$ Conversely, an expression of above $-30°C.$ indicates warmer than $-30°C.$ All temperature expressions are in degrees Centigrade.
O.A.T.:	The outside air temperature or ambient temperature recorded at ground level or at altitude.
Hotwell-Hopper—Partial circulator:	This is a compartment fitted in the aircraft main oil tank for the purpose of ensuring that warm and/or diluted oil is supplied to the engine immediately on starting. There is no standard single term for this at present.
A.M.P.G.:	Air miles per gallon.
C.F.:	Chill factor.
E.O.I.T.:	Engine oil inlet temperature.

DISCUSSION

S. Scott Hall (PDTD(A), Ministry of Supply, *Fellow*): The Paper described work which was the result of collaboration between personnel from Great Britain and from Canada. The importance of starting and maintaining development and research work in the Dominions needed no emphasis; but perhaps only those who had been into it carefully would appreciate the difficulty of doing this kind of work, in an area far removed from large centres of industry and without all the resources which went with that industrial background.

The Paper had indicated how highly successful this particular work had been under conditions which most of them would find difficult to appreciate. The work had been of tremendous value to them in the operation of aircraft in very cold weather conditions.

The Paper was a record of experiences and results in operating aircraft in very cold weather conditions at ground level in a certain part of Canada. To what extent were those conditions representative of cold weather conditions in other parts of the world? To what extent were the problems discussed by the authors common with those that would be met in designing aircraft for operation over long periods at very high altitude? The authors had pointed out that that matter had not arisen so far, because aircraft had not been able to maintain such heights for sufficiently long periods. But surely the effects of differential contraction, etc., would present problems which designers must commonly meet in modern practice?

He wondered to what extent the use of the refrigeration equipment available in countries such as Great Britain would have given the answers to the problems faced by the Winterisation Unit. Did the authors consider that trials in a refrigerated hangar such as the Americans used at Eglin Field would render unnecessary some of the trials conducted in northern Canada?

He regretted that the authors had not dealt more extensively with problems of equipment; it would be interesting to know what the experience had been in dealing with very delicate equipment such as radio gear, with its multitude of small terminals, and so on. It would seem that the only way in which to deal with such equipment would be to take it out of the aircraft and deal with it in a warm workshop. Had there been any difficulty in doing this under these climatic conditions?

He had been rather surprised that a good deal more work was thought to be required with regard to clothing for personnel working in very cold conditions. Surely a great deal of information was available on clothing for those operating in such conditions, both as the result of exploration and also possibly as a result of work by the R.A.F. Institute of Medicine? He would like the authors' comments on that question. What future developments could they foresee?

G. R. Edwards (Vickers-Armstrongs Ltd., *Fellow*): He was impressed by the ability of human beings to endure the sort of conditions described rather better than could the aircraft with which they were dealing. The experience of some of the members of the Aircraft Industry in Great Britain, who at times during the past few years had undertaken trips to the Far East kindly organised by the M.O.S. in order to experience conditions in hot and wet climates, might well be repeated if others were enabled to gain experience in dry, cold and apparently windy conditions; he would suggest that the actual personnel who had experienced the hot and wet conditions might possibly be excused the additional experience of the cold and windy!

He was cheered by the apparent ease with which jet engines competed with temperatures of $-47°$ and $-50°$C., and a little surprised by the apparent ease with which turbine fuels also competed with the same temperatures without any signs—at least, he assumed that they competed without any signs—of wax separation. He had heard some rather gruesome stories about wax separation at temperatures of about $-40°$C., and would be grateful if the authors could throw a little more light on that subject.

He was rather worried that they were likely to become a little too enthusiastic about making a single aeroplane able to compete with equal success with conditions in the Yukon, in Timbuctoo, in Singapore and other odd places. They should take stock of the position; they were asked to make it possible for aircraft to work under widely varying conditions so that they could be made capable of some form of operation in each place. He would have thought that, if it were necessary for a squadron to go to such a place as the Yukon, it was not unreasonable that the aircraft should be specially equipped, and

to an extent, specially prepared for that particular job.

The information given in the Paper would be of great value so far as the operation of aeroplanes at high altitudes was concerned. That operation would be much easier, in a way, than that with which the authors had been concerned, because there would be pressure cabins with the heat available to keep a lot of the equipment in a reasonable condition, which it would not be able to do when standing on the ground in a very cold climate.

Differential expansion and contraction was important and he believed that a steel was being produced in considerable quantities with a coefficient of expansion comparable with that of light alloys. That might ease their task.

Sometimes he had wondered whether the same degree of urgency that was applied to the development of the aircraft itself was also applied to the equipment and accessories that went into the aircraft. If it were to be the policy for aeroplanes to operate under the conditions described by the authors, he would have thought that the standard equipment issued for those aeroplanes should all be capable of operating with the same degree of efficiency as in the normal practice. But his experience recently had been that such was not the case, that certain pieces of equipment for aircraft had to be specially prepared in small quantities in order to ensure that it would function.

Group Captain V. H. Patriarche (R.C.A.F.): Winter operation presented no really great problem, but it did present a great many small ones. There were a thousand and one irritating little things which caused trouble to personnel and to the equipment and the job of the Winter Experimental Establishment was to overcome those, rather than to build new aeroplanes. In Canada they had been operating in the bush and the Arctic for some twenty years, and they had operated fairly consistently throughout the winter.

As a matter of interest, at his home at Winnipeg the temperature would come down from time to time to −50°F.; those low temperature conditions might persist for two or three days. The lowest Canadian temperature recorded was a little below −80°F. in the Yukon; he believed the period of that cold snap was the better part of a week, although at times it was a trifle less cold than that. The general experience was that, down to about −50°F., the troubles caused by temperature drop did not increase very much; it was mainly a question of wind. Below that point troubles seemed to multiply, both for personnel and the equipment.

A man who was working out of doors at temperatures of −50°F. and below found that his work was slowed down not so much by the deterioration of his mental or physical powers—although there was greater fatigue at those low temperatures—as by the necessity for going back into the mess from time to time, having a cup of tea and warming his hands. He had a snapshot of one of his men doing an engine service at a temperature of −48°F., when there was a wind of 10 m.p.h. Normally such a service would take about two hours, but in those conditions it had taken roughly five hours. The engine had had to be re-heated several times in order to turn it over, as it was before the days of oil dilution. A blow torch had to be used to free the grease and set the tappets. It was not a very accurate job. The mechanic had to work with bare hands for a good deal of the time, when dealing with small parts such as magnetos, and this meant he had to take off his mitts, pick up tools which had been kept warm in a bath of hot kerosene and, when his hands became cold, he had to put on his mitts again and warm them.

The Winter Experimental Establishment was developing new criteria which could be standardised for design of aircraft, engines and auxiliary equipment. If aircraft were to be operated commercially, even in the lower latitudes of Canada, they must be capable of withstanding conditions of severe cold; they must not be grounded under these conditions, but must be capable of operating every day. They must be capable of operating in temperatures of −50°F. and preferably lower. If in the future they went into trans-polar operation they must expect to have to deal with that sort of temperature, although normally the conditions were not so bad over the polar seas as inland. It was most important that they should get from the work of the Winter Experimental Establishment that type of design criteria to which the authors had drawn attention. They must operate aircraft in order to find out what was likely to go wrong, and make provision so that designers could ensure that it would not happen again.

Cold weather working should be treated in

two different phases. In the first phase, a new product must be taken from the manufacturer's shop, made to work in cold conditions, under the control of experienced men and with the aid of facilities which would enable the necessary modifications to be produced on the spot, and the job re-designed, as it were,as a cold weather aircraft. The second phase was to determine how the aircraft could be operated by normal personnel. Crews who were working steadily on experimental work of that type would do a far better job than an average group of mechanics from a civil company or from the Service. Fully half the problem was that of teaching the personnel how to work in those cold conditions; how to live, what to eat, and how best to protect themselves from cold and wind. In that further stage of development, having produced the cold weather aeroplane, an ordinary crew should be allowed to fly and maintain it. They would then find a whole new group of minor problems which would have to be solved, and they would also have a type of training for personnel which could be given only by experience and could not be taught theoretically.

He emphasised the importance of avoiding too academic an approach. Very low temperatures were encountered quite regularly in many parts of the world and aircraft had to be operated consistently in such conditions. The aeroplanes, engines and equipment must be able to operate for 365 days of the year.

E. J. R. Clark (Chief Draughtsman (Production), Vickers-Armstrongs, Weybridge): The authors had emphasised the need for providing warmth for the navigator of an aircraft: but it seemed to him that, for aircraft operation under very cold conditions, other members of the crew must also be considered; there must be occasions when they also had to work with bare hands.

Other matters in regard to heating, for which information was required, were the provision for drinking water, toilets, and so on.

It was said that the atmosphere was mainly cold and dry in that part of the world where the authors were working; he would like some assurance on that point and some information as to whether there was any degree of humidity and, if so, to what extent. It raised in his mind problems which had to be faced in connection with servicing equipment and the supply of spares to the tropics. Special precautions had to be taken in the packing of such equipment, in view of the special conditions which had to be met, and some special precautions might also be necessary in connection with equipment for the servicing of aircraft in very cold conditions.

Mr. Wilson had said that for aircraft paint finishes the smooth finish was definitely better than that provided by the camouflage paint; it would be interesting to know how the powers-that-be would react to that in respect of meeting the requirements.

He emphasised the necessity for the issue of the necessary information to the Industry at large. At the moment some valuable information was being given by men such as the authors, and limited issues were made by the Ministry of Supply only to the contractors whose aircraft were for test at the W.E.E. Particulars of work which was a year or two old were sent from time to time to those concerned, but he thought that, in respect of conditions which had been described in the Paper, some means should be found for issuing reports earlier to the Industry at large, and particularly to accessory manufacturers.

C. G. A. Woodford (English Electric Co. Ltd., *Associate Fellow*): It was gratifying to learn that so little trouble had been experienced with electrical equipment in cold conditions, apart from the cracking of P.V.C. cable coverings; perhaps that cracking was to be expected and they did hope that the use of P.V.C. for aircraft would die out after the war and be replaced by natural rubber, and glass covering.

The authors had referred to the use of D.T.D. 577 and of D.T.D. 539 in particular. He believed that D.T.D. 539 was one part of D.T.D. 577 and two parts of kerosene. He believed it was also true that it had been used as a high altitude control lubricant; but he warned that it was of precious little use for the lubrication of ball bearings, for the kerosene and oil would creep out and leave the soap in the bearings. That had been borne out by his tests on low-power motors, and so on, in temperature conditions down to about $-50°$F. It seemed almost impossible at the moment to use any sort of grease lubricant in bearings of that sort for small motors which were used only for a very short time, such as for the operation of valves, and hydraulic and feed valves in particular; the period of operation might be only

a second or two. He believed the answer would be the use of a form of dry bearing which possibly had been dipped in colloidal graphite.

Another problem had arisen in that connection. He had heard that some mysterious failures had occurred in a submerged petrol pump at very low temperatures, and his experience would perhaps indicate the possible nature of that trouble. Using the same type of brush gear on some of the special type motors and subjecting them to low temperatures in the cold high altitude temperature chamber, the brush holder shrank on to the brushes and gripped them; but the commutator then continued to contract, so that there was no contact between the brushes and the commutator. That had rendered the motors inoperative at the low temperature. It had also assisted in the promotion of an ice film on the commutator, which was probably exaggerated in that particular test, made at low temperature, not necessarily corresponding to a particular altitude; so that there was more moisture present, causing greater condensation.

The figures had been investigated for very small motors in which the full load torque was only a matter of two to three inches. He had investigated the quantitative nature of the torque absorbed by the motor bearings at those low temperatures, using the lightest type of ball bearing that could be fitted, and had found that at −47°F. the bearings, lubricated with D.T.D. 577, actually absorbed 50 per cent. of the rated motor output torque at the rated speed. He had also found that the torque absorbed by the bearings was relatively constant for a particular temperature.

The method of test was to apply reduced voltage to the motor, which was driving nothing, so that the load on the motor was merely the load of its own bearings. The results tended to show that the speed at which the motor ran was related fairly closely to the voltage applied. He had taken the range of from 100 down to 40 per cent. of the designed speed and had applied reduced voltages over that range for periods of a few seconds at a time. There was a constant bearing torque drag at each of the temperatures used, and that torque at −47°F. was about half the rated output torque. That would not be important in very much bigger motors; but as they were often concerned, particularly in the get-away, with small motors for operating valves, and so on, those relative magnitudes were well worth bearing in mind.

R. H. Woodall (Rotor Ltd.): He had been interested in the authors' experience in starting engines under low temperature conditions. He believed it could be said now that clutches had refused to slip because the lubricant between the plates had become solid. Some success had been achieved in finding a way out of that difficulty by using dry plate clutches, and the results of further tests in Canada were awaited.

Had the authors had difficulties in starting propeller turbine units in extremely low temperatures? From certain results obtained to date it was felt that the power of the starter motors might have to be increased, unless some dilution of the oil in the propeller gearbox could be effected; the powers required at low temperatures were likely to increase considerably for the propeller turbine, because of the losses in the gearbox.

He was also interested to hear of the possible use, for starting purposes, of the nickel - cadmium or nickel - iron alkaline battery. He would have thought that the internal resistance of that type of battery was definitely against its use for starting purposes; for a given capacity the internal resistance was considerably higher than that of the lead-acid type. Such batteries had been used by Imperial Airways (now British Overseas Airways) before the war on "C" class boats, among others.

He supported the plea for the development of greases which would be satisfactory at temperatures down to −70°C.; specifications issued by the Ministry of Supply were now demanding that equipment should actuate at that temperature, but it was found that so far, in Great Britain at any rate, there was no grease avaiiable which would enable that to be done. What was the authors' opinion of "Silicones" grease, which, while it gave a break-away at −70°C., appeared to lack lubricating properties at that temperature?

Wing Commander J. Jewell (*Assoc. Fellow*): He agreed with Mr. Scott Hall that, while studying the Paper, they must be careful about the conclusions they drew. The illustrations put forward were applied to single aircraft, or at the most, to two aircraft.

As one connected mainly with military aircraft, he could see the military problem, which was not to operate, say, two Vampires, but more nearly 200 Vampires. In future it

would be necessary for military aircraft to strike objectives situated probably at long distances from the aircraft base. Therefore, could they examine the high-altitude, low-temperature conditions in the light of the results given in the Paper? It might be better that bomber aircraft should be based in much more comfortable climates than in the very cold conditions with which the authors had been concerned. He had been most interested in the authors' remarks that most of the difficult problems seemed to arise on the ground. If that were so, let them put a little more fuel into the aircraft, go to a warmer place and start from there.

The Paper had not mentioned radar, which it would be necessary to use in seeking objectives. He understood that radar sets were very critical and would probably have to be warmed up on the ground before take-off. But how would they be warmed up? Would the aircraft electrical system have to be used, thus making great demands upon it? A reference had been made to the use of electrical controls instead of mechanical controls to operate the control surfaces. This would further increase the electrical load. It had been said of military aircraft of the future that the demand by radar and other equipment on the electric power services were such as to require enormous installations, sufficient to make some designers consider giving up the design of military aircraft altogether, and looking to something more simple and utilitarian.

He had observed recently that the cockpits of military aircraft tended to become smaller; the operation of controls, reaching for this and that, became more and more complicated. Would the complication be increased even further if the person occupying the cockpit had to be dressed in clothing such as that illustrated by the authors of the Paper, and which was worn by the personnel at the Winter Experimental Establishment?

Those were one or two of the problems which the designers of military aircraft at any rate should think about; they should not rush off to their drawing offices immediately and initiate modifications to cater for all of the problems raised in the Paper.

N. E. Rowe (British European Airways; Vice-President of the Society, *Fellow*): He felt that Group Captain Patriarche had achieved a triumph of under-statement when he had remarked that they should avoid too academic an approach; indeed, it was difficult to imagine anything more severely practical than the manner of conducting the work.

One of the important points to be borne in mind was, as had already been stated, the application of the authors' results to high altitude flight. Many of the items which had given rise to difficulty on the ground were likely to give rise to difficulty also in protracted flight at great heights, when aircraft might experience even lower temperatures than the averages of those discussed in the Paper. In particular he had wondered about the recurrence of ice in the fuel, particularly for turbine engines under such conditions. Would the authors give their opinions on that matter? Because of the little vapour that was in the air at temperatures such as those at which they had been working, they had not found the formation of ice crystals in the fuel; but if fuel were put into the tanks under the more normal conditions of humidity of temperate regions and it was then taken to a high altitude, where temperatures were very low, was that trouble likely to occur?

He emphasised the point made during the Discussion that the work described in the Paper was important because it established design criteria.

In particular, he was impressed, perhaps wrongly, by the poor behaviour of synthetics and rubbers and materials of that sort. Such materials were often of the greatest value to designers and engineers because of their flexibility in many applications, but under conditions of very low temperature they seemed to give trouble. That matter needed to be borne in mind carefully in connection with high altitude flying.

It had been suggested by Mr. Wilson that the rubber seals could be so re-designed that they would behave in a satisfactory way under low temperature conditions; he would like confirmation of that, for he had noticed a difference between hydraulic and pneumatic systems as stated in the Paper; pneumatic systems, particularly with rubber seals in the pipe joints, had become deflated, whereas hydraulic systems had stood up pretty well in conditions of dispersal at very low temperatures. His conclusion was that the fault was that of the rubber; for perhaps in the hydraulic systems, although the rubber seal was poor, the high viscosity of the fluid rendered it difficult for that fluid to leak. He would like the authors' comments.

In the ground equipment jacks the seals were made of leather and they had given no

trouble. It might not be possible to use leather seals in all aircraft hydraulic components, but the matter was important.

There was the general problem of power-operated controls in aircraft flying at great heights, particularly the kind which used hydraulic transmission, and especially at points away from the heated parts of the aircraft. The effect of prolonged low temperature on the efficiency of such systems would require most careful study and test.

He had been impressed by the reference made during the Discussion to the trouble experienced with small equipment for transient use; that constituted a very real problem, for it involved the particularly difficult job of lubrication. Clearly, lubrication was a matter of cardinal importance in operation at very low temperatures.

References had been made to tests in refrigerated chambers or hangars, followed by a large scale test using numbers of aircraft and comparatively inexperienced crews. He imagined that all those methods would be used; the laboratory method for work on pipelines, cables, and so on; the refrigerated hangar for the extension of that work; and finally, the full-scale trials; that was the only way in which to arrive at the final answer.

Maxwell Smith (Shell Aviation Dept.) *contributed*: He gathered that Squadron Leader Bridgland considered the lubricating oil system and oil dilution one of the most important factors, if not the most important, in the problem of cold starting of engines.

This was a problem which, as mentioned by an earlier speaker in the Discussion, could be studied in a cold chamber more conveniently than in Arctic climates, where the investigators were handicapped by the terrible conditions.

A study of cold starting had been made at the Aero-Engine Research Laboratory at Thornton, using main engines in a cold chamber capable of operating at −40°C. One aspect of this work had covered the oil dilution problem and had determined the effective reduction in cranking torque which could be gained by various degrees of engine oil dilution by means of the Worth system. They had found that oil dilution was progressively effective in reducing low temperature cranking torque up to at least 50 per cent. dilution, but that more than half of the diluent might be lost by evaporation unless the dilution was done in a sufficiently short period of time to avoid recirculating the diluted oil. It was advisable, therefore, to use a large jet for priming, otherwise the effective dilution would be less than expected and impossible to calculate without analysis of the sump oil.

Squadron Leader Bridgland mentioned that one of the great difficulties with the dilution process was the excessive frothing or gassing of the oil due to the fuel boiling off as the engine warmed up. He might, therefore, be interested to try the effect of direct dilution of the oil on the cylinder walls by the simple method of cranking the engine at slow speed with the engine cold, or partly cooled down, and at the same time priming. The Thornton tests had shown that by combination of oil dilution, in the ordinary way, with a subsequent cranking and priming operation, it was possible substantially to reduce the cranking effort for low temperature starting, and thereby avoid excessive dilution of the engine oil. In their tests it was shown that a 10 per cent. oil dilution, followed by priming reduced the cranking torque approximately to the same extent as would a 20 per cent. oil dilution alone, while 20 per cent. dilution with priming was equivalent to about 50 per cent. dilution.

He was interested to read in the Paper that new priming systems were under investigation, using either atomised fuel or injection at the inlet valve of each cylinder. This would, no doubt, be a welcome development since it had been shown that with the conventional priming systems, not only were special cold starting fuels required for low temperatures but, because the vapour pressure of the fuel decreased exponentially with decrease in temperature, the useful range of temperature in any one special priming fuel was rather restricted, so that several fuels of different volatilities covering limited ranges of starting temperatures might be needed when very low temperatures were encountered.

THE AUTHORS' REPLY

Mr. Scott Hall: In reply to Mr. Scott Hall's question as to how representative the conditions described in the lecture were of other parts of the world: information available indicated that the average temperatures shown in Fig. 1 of the Paper were, if anything, slightly less severe than those existing in Greenland and northern Asia at comparable latitudes. Unfortunately, they had no figures available on average tempera-

tures in the Antarctic. As Fig. 1 indicated that conditions were less severe than those laid down as requirements for Arctic operation, it was pointed out that the temperatures indicated were the average for the coldest month over a period of years and did not indicate the minima which might be encountered for several days at a time. It was interesting to note that the Air Conditioning Engineer's Atlas, published in the United States, recommended that heating plants in the three central northern states below the 49th Parallel be designed to meet requirements at an outside air temperature of -30°C.

Operating at low temperatures in flight was a rather different problem from operating at low temperatures on the ground. In flight the low temperature zone was entered with the aircraft operating normally and such problems as starting the engines, and warming up oil systems and cockpits were not encountered. The problem of differential expansion and lubrication was to some extent alleviated by the heat radiated from the engine, but with the trend to make cabins and cockpits smaller and more self-contained for higher altitude operation, these problems might become similar to those described.

It was their opinion that many minor unserviceabilities and defects which occurred during Arctic operation could be prevented by adequate testing of components in cold chambers, likewise, some of the major problems; preliminary proving of complete aircraft could be accomplished in refrigerated hangars such as that at Eglin Field. It was not considered that tests in a refrigerated hangar could be regarded as a substitute for actual service trials where aircraft and personnel were subjected to the rigours of the Arctic.

Mr. Scott Hall was correct in assuming that maintenance of intricate equipment required that the item be removed from the aircraft and serviced in warm shelter. For this reason, it was essential that equipment of this type be designed so that it could readily be removed from the aircraft by personnel wearing winter clothing.

A good deal of work on clothing was required. While a great deal of experience was available from explorers and inhabitants of the Arctic, there was at present no suitable clothing which met the requirements of the Air Force that clothing be capable of keeping airmen warm while relatively immobile during flight and still not be too bulky to allow freedom of movement on the ground, whether for survival in the case of emergency, or for airmen doing routine servicing. New types of clothing for use in the Arctic were required which provided better insulation, adequate protection for the head and face and, at the same time, were less bulky to allow personnel greater freedom of action when working on aircraft.

Mr. Edwards: No difficulties had been encountered with waxing down to temperatures of -50°C., the kerosene in use having been supplied to Canadian Specification C-36-1 which was very similar to DERD. 2482. Both specified a maximum freezing point of -40°C. which indicated that kerosene supplied to meet the other conditions of the specification did not freeze at -40°C.

Regarding the suggestion that it was too much to ask that one aircraft be required to operate in extremes of both hot and cold, it was pointed out that if operation should require that an aircraft based, say, in the Yukon, be shifted to a coastal base in, say, British Columbia, the average difference in daily temperatures encountered would be 40°C., whereas the annual variations in daily temperature over the year at a base in the Yukon would be 55°C. As those figures were based on average daily temperatures for the month, it was quite probable that much greater variation in temperature would be encountered either by moving a relatively short distance (1,200 miles) or by leaving the aircraft at one base during the entire year.

Group Captain Patriarche: They greatly appreciated his generous support, amplifying some of their views and including others of his own. Mr. Wilson, particularly, had known Group Captain Patriarche for a number of years, particularly when the latter was stationed in the north-western parts of Canada, and was able to benefit from his many years' experience of cold weather operation of aircraft, which was conducted during the days when operating facilities were practically non-existent.

Mr. Clarke: It had been found by the crews at the Winter Experimental Establishment that, with the exception of the navigator and wireless operator, all had been able to accomplish their assigned tasks with some form of gloves. In regard to drinking water, it was normal to supply hot coffee or hot soup during the actual flight and the requirement

for water had not proved a problem. However, if drinking water were required, the insulation provided by the standard thermos flask was sufficient to prevent it from freezing. During winter operations no difficulties had been encountered with chemical toilets but a certain amount of difficulty with relief tubes freezing had been experienced.

It was quite true that during the winter at the test bases, the atmosphere was cold and dry and while the relative humidity of the air was very high, the actual water content of the air was low; for example, with a relative humidity of 100 per cent. and a temperature of -30°C., the actual water content was .36 grammes per kilogramme of dry air.

Because of the low humidity in the Arctic, the corrosion of equipment was much less, but care must be taken not to ship articles coated with heavy grease such as lanolin, resin to Specification D.T.D.663, or other protective coating, which became hard at low temperatures and almost impossible to remove. They would suggest that spares and items shipped to the Arctic regions would be reliably preserved if they were encased in a plastic cocoon.

Mr. Woodford: They agreed that grease to Specification D.T.D.539 was not a satisfactory lubricant for small motor bearings.

Mr. Woodall: While no tests had yet been conducted on gas turbine propeller units, it was thought that major problems would exist in starting unless it was possible to use some form of dilution or operate with a less viscous oil. As they had had no experience with silicone greases, they were not qualified to express an opinion.

Wing Commander Jewell: If the Service were prepared to subjugate tactical plans to the ease of operation and maintenance of their aircraft and the comfort of their personnel, and were prepared to sacrifice aircraft which might have been diverted to Arctic bases because of weather or other emergencies, then it might be possible to ignore the requirements of Arctic operation. Further, if the same policy that had been suggested for bomber aircraft be adopted for fighters, it was apparent that bases for these aircraft would have to be in the same area and the effectiveness of the fighter escort and interception would be greatly reduced.

It was not intended to deal with the subject of radar in the Paper, but as the question had been raised, they could assure W/C Jewell that radar sets were not as critical in low temperature conditions as would be imagined.

The problem of a large pilot wearing Arctic clothing in a small fighter aircraft was, as he had pointed out, a very real one and would become worse if cockpits decreased in size.

Mr. Rowe: Provided that the precautions outlined in Section 5.7.2 were taken, it was considered that little trouble would be encountered with ice crystals forming in the aircraft fuel system. They agreed that seals could be designed to operate satisfactorily under Arctic conditions and that the difference between hydraulic and pneumatic systems rested mainly with the working fluid.

Mr. Smith: They agreed that the rate of dilution was a definite factor in the amount of diluent required, 30 to 35 per cent. dilution being about the limit with the rate of dilution in general use. The results quoted by him for cylinder priming in conjunction with oil dilution were very impressive and the procedure undoubtedly had merit. However, they pointed out that the cranking of the engine required during priming would undoubtedly displace a certain amount of oil from the Hotwell and might cause the make-up oil to enter the tank outlet with the danger of causing oil starvation on the following engine start. It was also probable that the engine manufacturers would view with disfavour the complete lack of lubrication on the cylinder walls.

MR. WILSON, in a brief comment on the Discussion, said that he and S/Ldr. Bridgland were very pleased by the Discussion and the interest displayed in their Paper.

It had been said that at the Winter Experimental Establishment they had been operating on one or two of a type; they realised that a lot of their results would have been different if 200 or 300 of a type were used. He agreed with that fully as did others, not only in the U.K. but elsewhere, and said that investigations on these lines had already been initiated by others.

SOME DEVELOPMENTS IN AIRCRAFT PRODUCTION

by

D. C. ROBINSON

The Paper was read by Mr. H. Smith, Works Manager of Handley Page Ltd., in the absence of Mr. Robinson because of illness.

WITH all transport vehicles a light structure weight is of prime importance. Light weight vehicles require less power to accelerate, less braking to stop, less power to climb hills. The power/weight ratio broadly determines the ability of a vehicle to get out of difficulties, avoid collision and, generally speaking, settles the vehicle's performance characteristics.

This is particularly true of the aeroplane where, with a third dimension of travel, the effect of gravity is present to a degree unknown to sea or land travel, even in mountainous countries.

Weight saving thus becomes of paramount importance in aircraft design and leads inevitably to the conclusion that nothing should be carried in the aeroplane to fulfil a service which can be satisfactorily and safely performed on the ground.

A further result, and one that most concerns us here, arises from this weight factor. In many trades a great deal of the technical execution of the work in detail is carried out in accordance with the superintendent's or foreman's knowledge and craftsmanship, and whether there is a little more—or less—material used is a matter for commercial considerations of cost, rather than one of necessity to save weight in order to fulfil performance.

The 754th Lecture read before the Society—on Thursday, 28th October 1948 at the Institution of Civil Engineers, Great George Street, London, S.W.1. In the Chair, the President, Dr. H. Roxbee Cox, F.R.Ae.S., F.I.Ae.S.

Mr. Robinson is Works Superintendent, Handley Page Ltd.

In contrast, there came at the very beginning of aircraft design and production the essential need to save weight. Apart from its physical inertia, avoidable weight is a costly luxury. It is estimated for example, that in the case of the Hermes flying 3,000 hours a year, the operating loss, excluding overheads, is of the order of £18,000 for every 1,000 lb. by which the payload is reduced. Saving can be effected in many ways: in the right selection of material, in precisely defining the measurements of detail parts and in using metal sheets whose thickness is within a close tolerance for the gauges specified.

In the pioneer days when production was small, hand methods were the order of the day, the design was embodied in dimensional sketches rather than drawings, and the dimensions marked out by hand on the detail parts themselves, instead of as later, on templates, to provide a series of similar and interchangeable parts.

Skilled men therefore, were required to set out and make parts, and skilled inspection was needed to make a supervisory check to ensure compliance with the required measurements.

The first World War saw the struggle of production to emerge from hand methods by the few, skilled in the art, to repetition-manufacture broken down into operations sufficiently limited in character to enable semi-skilled or unskilled rapidly to be trained for their safe execution.

With the advent of the all-metal aircraft in the inter-war years, the need was intensified for jigging and tooling and, during the last war, still more was the need apparent to eliminate every phase in successive operations where human fallibility could introduce error.

Thus, the problem of aircraft production has been and will always be—because of the

weight control that must be exercised—that of producing parts, assemblies and components, which are correct in dimensions, and of strictly controlled material, so that no unnecessary weight is included.

Over such a precise state of manufacture hangs the shadow of modifications—changes to details and components alike—necessarily arising from widening experience and improving technique of operation.

Then, too, the factor of time must always be taken into account. If an aircraft takes too long to design, test, jig, and put into production, it will be out of date by the time it is in operation. Always, therefore, the aircraft manufacturer has to bear in mind that the longer time the aircraft takes to produce, the more exacting will be the competitive performance which the aircraft has to meet. Thus, while production is defined in the dictionary as " to make or manufacture," aircraft production has to take into account the time factor, and production therefore, is a continuous challenge between man, material and time. Accordingly, methods which are suitable for long runs of continuous production, where the basic design technique of the vehicle to be made is only slowly changing, are quite unsuitable for the production of the smaller numbers that are called for in aircraft manufacture, and for a continuously varying set of requirements expressed in demands for modifications.

Here then is the basic problem of aircraft —to manufacture an article by methods capable of rapid expansion for large and efficient production, and at the same time flexible enough for changes in design to be introduced rapidly. Every effort must be made to simplify and cheapen the tooling of an aircraft—usually a long and costly procedure—and thus save money, and more important still—time.

First let us consider the MAN. The most important factor is the quality and qualifications of the personnel who do the work in offices and works. Designers and draughtsmen must appreciate not only the reason why the operating user calls for certain requirements in the original specification and in subsequent modifications, but also be able to translate, through drawings and schedules to the production shops, the buyer's requirements in a form that is practical and can be manufactured. The production staff must evolve and develop efficient manufacturing methods and tools which conform to the flexible nature of the art. With every aerodynamic advance made, production technique must be in step, or delays will retard the speed of progress.

The two World Wars undoubtedly gave to the Aircraft Industry, both in design and production, that extra impetus and, in consequence, progress which might not have been achieved otherwise for many years to come. In reflecting on what has been done in the past, the future surely can have no problems that cannot be overcome.

The keynote of success lies in having practically-minded technicians and draughtsmen, and technically-minded production engineers, and above all, the closest co-operation between Drawing Office and Works.

The successful manufacture of any article and, in particular, of an aircraft, depends largely on close liaison between design, production and inspection. This liaison must exist at all times, from the inception of the design, through the project and development stage, drawing office and experimental shops, to the production line. The Works must play a large part in settling the way in which the major part of the design is schemed to be produced, and the Drawing Office must be production-minded in the way the schemes are developed in the detail design. This close contact should bring about a large degree of confidence between design office and works, and a respect for the other's point of view when at variance on any particular problem, always having in mind that no job is too difficult if the design makes for a better and safer aircraft.

This co-operation as an aid to production cannot be too strongly stressed. The better the liaison, the shorter the period from design to first flight, a period all-important to the designer and one which it is of vital necessity to keep as short as possible, in order to expedite the possibility of obtaining contracts and a follow-up production.

The basis for this spirit of co-operation is a common training under a good apprenticeship scheme. Efficient management can only be achieved and maintained by trying to understand and anticipate the problems of personnel. The individual, in his early years of training as an apprentice, must be watched and guided through the various departments of the works, his particular ability assessed and developed in the final staff and office

training in the branch of industry he intends to follow during the last year of his apprenticeship.

Promising apprentices should be attached to heads of departments and encouraged to use commonsense and tact, and on occasions should deputise in minor management affairs. As it will fall to these young men to continue management in their future years, this practical supervisory training is all-important.

Secondly, let us consider how the team of designers and producers is to work, for most efficient, rapid, and flexible production. Here some basic principles must be borne in mind.

1.1. The finest theoretical design, if mechanically unsound or liable to cause trouble in service in its final form, will always be ousted by a design of less theoretical perfection but which, mechanically sound, gives satisfaction in service. The design must therefore be mechanically sound and further, should be laid out from the start for reasonable methods of production.

1.2. Production on the assembly line should permit the greatest possible number of components of the same aircraft to be worked upon at the same time, so that the greatest number of man-hours can be concentrated simultaneously on a given aircraft, and the fewest number of aircraft worked upon at a given time for a given rate of output. In this way the elapsed time is a minimum between start and finish of assembly and erection, and the capital invested in work - in - progress is also kept to a minimum. Analysis of man-hours spent on the production of an airframe shows that between 75 to 85 per cent. of the hours are spent on assembly in one form or another. Assembly methods, therefore, demand close investigation, to see in what way assembly man-hours can be reduced. Several methods suggest themselves: —

1.2.1. The breaking down of assemblies and sub-assemblies into a number of easier operations.

1.2.2. Correct and pre-drilled detail parts.

1.2.3. Larger detail parts—conditioned by the size of presses available, and manhandling.

1.2.4. Fewer detail parts—by the introduction of pressed flutes and depressions for strength and stiffness.

1.2.5. Equipment assembly outside the constructional jigs.

1.2.6. Standardisation of detail parts—difficult except on long-run contracts.

A final word on details. Anyone connected with the production of aircraft will appreciate the wisdom in the saying "Take care of the details and the assemblies will take care of themselves." It would be too difficult to calculate the number of man-hours lost on assembly through detail parts not being correct or available on time.

1.3. To achieve easy means of fabrication, the decision must be made to have no drilling on assembly. This requirement emphasises the need for accurate tooling of the details.

2. In the evolution of the design from the designer's brain to the finished drawing, thence to tools for production, and finally to the manufactured article, *mechanical processes of reproduction* must be used to the maximum, so as to minimise the need for the transfer of technical data, measurements, etc., by skilled personnel and, more important still, so as to reduce the possibility of human error.

ERECTION AND ASSEMBLY

The first stage is the settlement by discussion and agreement between Drawing Office and Works as to the way in which the design is to be broken down into its components and assemblies in sizes suitable for manufacture and perhaps transport. The second stage is when the Jig and Tool and Production Departments still further break up these into assemblies and sub-assemblies. By this method, labour is more evenly distributed with the maximum efficiency, tending to greater output, and the maximum number of men can be engaged on an aircraft at a given time. If we accept—as indeed we must—that safety is the governing factor in the construction of an aircraft, it will be readily agreed that the more an assembly is broken down, the easier it becomes for inspection to be made throughout the stages of manufacture.

The number of jigs for any one component, or assembly, and the time taken in any jig, will determine the rate of production, and

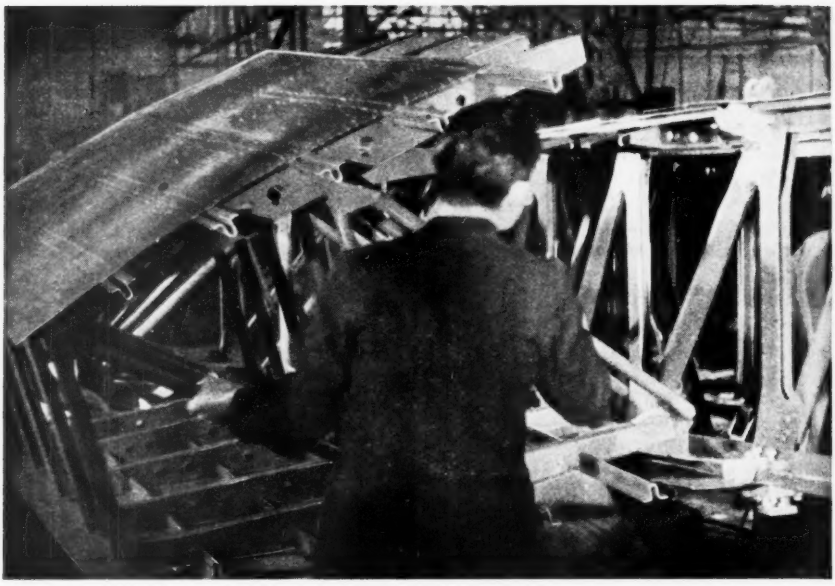

Fig. 1.
Assembling the nose portion of the Harrow wing to form the D-spar.

Fig. 2.
Section of Harrow D-spar completed.

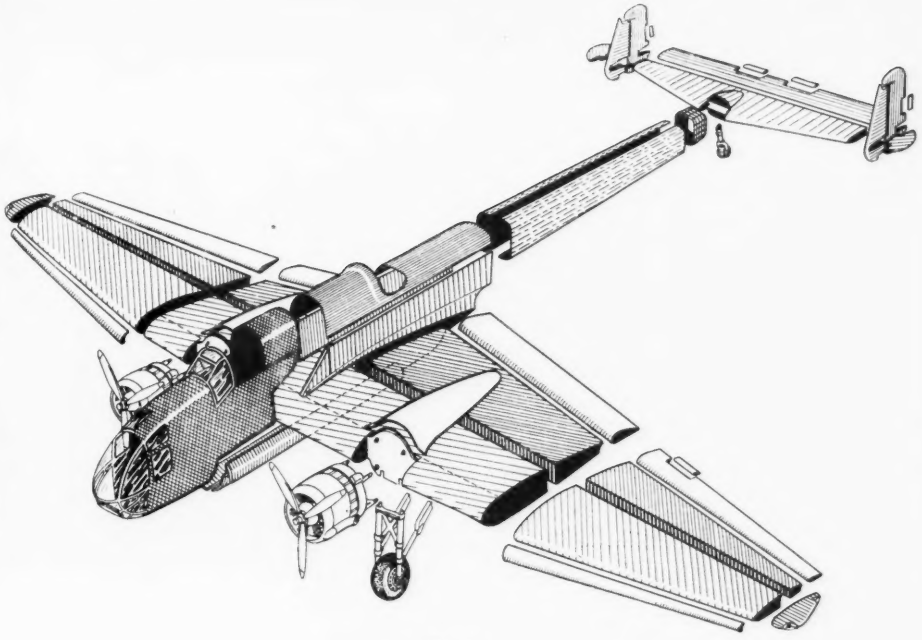

Fig. 3.
Hampden split constructional components.

also the floor space to be occupied. It is axiomatic, therefore, that the time in a jig should be as short as possible, and if there is to be a continuous production with day and night shifts in an emergency, operations in the jig should be such that they can be picked up and continued by successive squads of men.

It is a basic principle that, in order to use a jig to full capacity it must be confined to the main purpose for which it is designed. The manufacture of the detail parts and the equipping of the finished unit are operations subsidiary to its main function and should be performed outside the jig. If this principle is observed the time in which the unit occupies the jig is reduced and the capacity of the tool increased in consequence.

Furthermore, the efficient use of jigs depends upon the splitting up of the aircraft into components of a convenient size capable of using parts manufactured as sub-assemblies outside the jig and of producing units which can be fully equipped before assembly on the aircraft. It is by exploiting this avenue of production that a given programme can be achieved with a minimum expenditure on assembly jigs. This split form of construction was developed through a succession of aircraft, beginning with the Harrow and Hampden, which were the forerunners and show the way in which it was first employed.

The Harrow, a twin-engined bomber started in 1935 can be described briefly as a monoplane with a gun turret installed in the nose and another in the tail. The wing was composed of a centre section with an outer plane on each side, all three of which employed a metal-covered D-spar to which a fabric-covered rear tubular rib structure was attached.

The components of both wings and fuselage were split to reduce jigging time. The principle employed is shown in Figs. 1 and 2. The completed front portion of the centre section D-spar is shown being assembled to the main spar beam. This was the final erection operation and followed the assembly of the nosing from its own detail parts; in

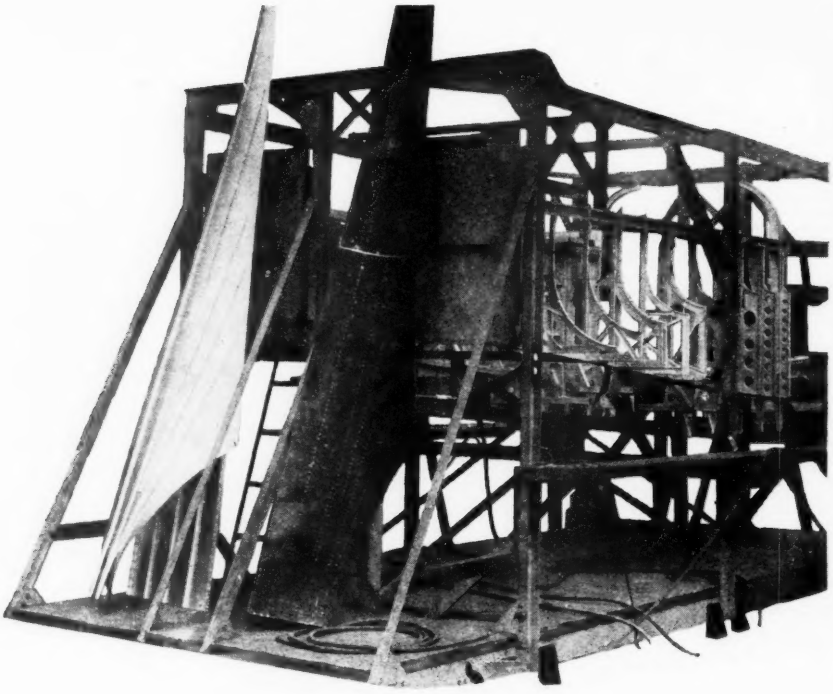

Fig. 4.
Hampden rear fuselage sides in assembly jig.

some cases these comprised separate skinning assemblies forming the upper and lower surfaces of the nose. It is noteworthy that at this date the details were accurately jig-drilled before assembly to avoid fitting work while the component was in the jig.

The methods initiated in the Harrow were so satisfactory that they were developed to the full in the Hampden in 1936. Here, in addition to the production problem of manufacture outside the assembly jig, there was the problem of installing the equipment and aircraft services in a fuselage having a maximum width of only three feet. This called for further splitting up of the main assemblies and, indeed, the aircraft was erected from the components shown in Fig. 3.

It may be helpful to recall the salient features of the Hampden design. The aircraft was a twin-engined mid-wing monoplane of all-metal construction and metal-skinned throughout (apart from the covering of the control surfaces). The fuselage consisted of three main parts: the front fuselage, the rear fuselage and the rear boom. The wing also consisted of three main parts: the centre section and the two outer planes.

Each fuselage side was assembled as a component in its jig, then removed outside of the jig to a stand where the services, equipment and details were easily installed. The front fuselage was made in one piece, but the rear fuselage was fabricated from three separate units; the two sides (port and starboard) being assembled opposite each other in a jig of sufficient width to enable work to proceed on both halves simultaneously, as shown in Fig. 4. On completion of the assembly, the sides were transferred to wooden stands arranged in a similar manner to the jig and in these stands the sides were equipped.

Figure 5 shows the electrical wiring in

progress. The main cable runs were installed in the aircraft in shallow channel-type conduits, as was the case in the Harrow. All possible assembly work was done at the benches, before installation in the aircraft.

Figure 6 shows the side fully-equipped. Fig. 7 shows the two equipped halves joined together to form a section of the fuselage. A top portion was used to close the fuselage section when the two sides were finally brought together outside the stand. This part is shown in Fig. 8.

The fuselage rear boom was constructed in a similar way but consisted of two parts only—the sides. These were joined by longitudinal seams along the top and bottom of the component. Each vertical side was assembled in a horizontal jig: Fig. 9 shows a half boom prior to skinning. A small rear tail bay, made as a single unit, was attached to the rear boom and this completed the fuselage.

The wing which, generally speaking,

Fig. 5.
Installing electrical equipment in Hampden rear fuselage sides.

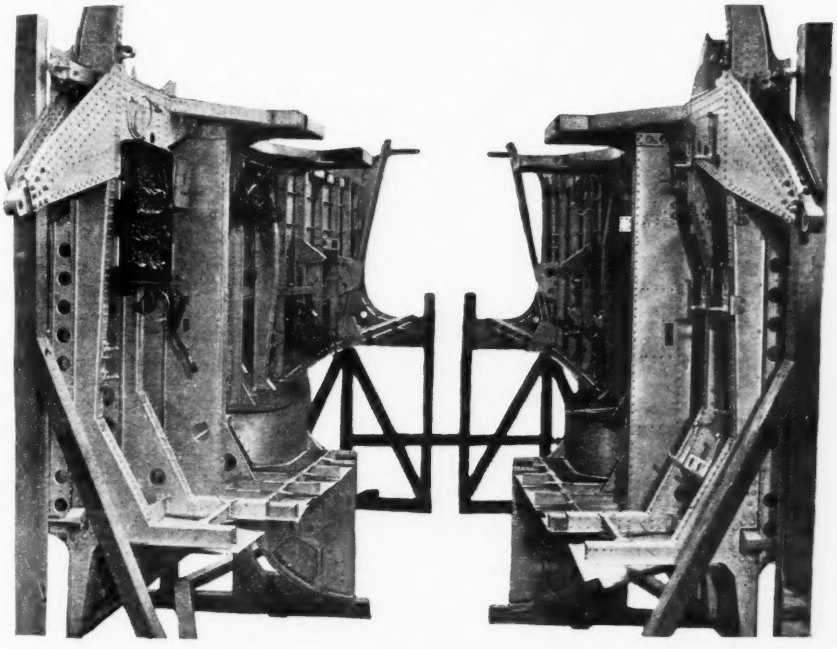

Fig. 6.
Hampden rear fuselage, sides fully equipped.

followed a design similar to that used on the Harrow, was constructed in sections. The D-spar of each wing was a complete component, the rear portion being metal-skinned and provided with a tail shroud, making it sufficiently rigid to form a sub-assembly capable of being handled.

The wing tips, tailplane and fins and the control surfaces were all manufactured as separate units outside, and then assembled in their respective jigs.

The split constructional methods ensured interchangeability of main components made not only by the parent firm, but also by daughter firms. Fig. 10 shows a typical erection of the Hampden by a Repair Organisation, using assemblies made by the parent and daughter firms, the erection being made possible by these interchangeability methods.

The Halifax design also started with an exploded drawing of components (Fig. 11) which formed the basis of the design work and from which the jigs were laid down for production.

The application of split construction methods to the Hastings production is shown in the next illustrations.

Figure 12 shows a Hastings front fuselage assembly; the floor, frames and stringers, having been pre-drilled, are assembled on a bogie and completely riveted together before transfer to the final assembly jig for the fitting and riveting of the skin.

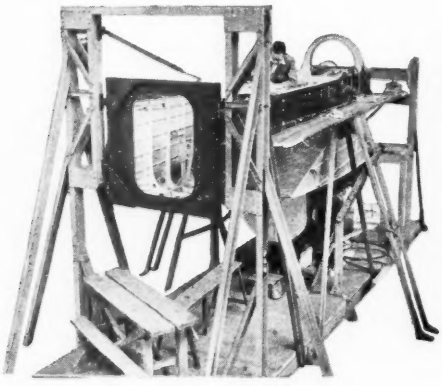

Fig. 7.
Hampden rear fuselage, two equipped halves joined in jig.

The Hastings rear fuselage is prefabricated in the same way—see Fig. 13. Note the heavy frames over the centre section area and also the bulkheads carrying the tailplane and fin attachments.

The intermediate and outer planes, both of which are of similar construction consisting of front and rear spars, inter-spar ribs and nose and tail portions, are pre-assembled as Figs. 14 and 15 show. For the intermediate plane the ribs are shown assembled to the front spar, prior to installing the rear and for the outer plane, the rear portion has yet to be fitted.

Figure 16 shows one half of the tailplane with elevator attachments fitted and also, the de-icing channels at the leading edge. The unit as seen here is completely riveted before transfer to the final assembly jig for the fitting and riveting of the skin.

Figure 17 shows the fin assembly on the same lines as the tailplane. As a matter of interest, it seemed to be asking too much to produce Hastings and Hermes fins, plus spares, out of the one final assembly jig, and yet get the required output, but by a concentrated process of elimination, every operation that was not absolutely necessary in the jig was done outside, and the required quantity per week produced, according to programme.

An important point needs to be remembered in connection with jig production. The jigs are elementary structures calling for no more technical data or instruction than any other works fixtures. The only dimensions of importance are the "pick-up" points of the component attachments. Given a skilled jig shop with supervision knowledgeable and skilled in the art, no drawings, other than the manufacturing drawings of the components or assemblies, should be necessary to make the assembly and erection jigs. Their production is quite different from that of aircraft part manufacture where drawings, precise to the last detail, are necessary, as numbers of parts have to be made to interchangeability limits and their size has to be accurately stated so as to keep within the required weight. Such considerations do not hold good for jig structures, which are not going to be reproduced in large numbers and so do not have to be interchangeable in their main structure, but only in their "pick-up" points.

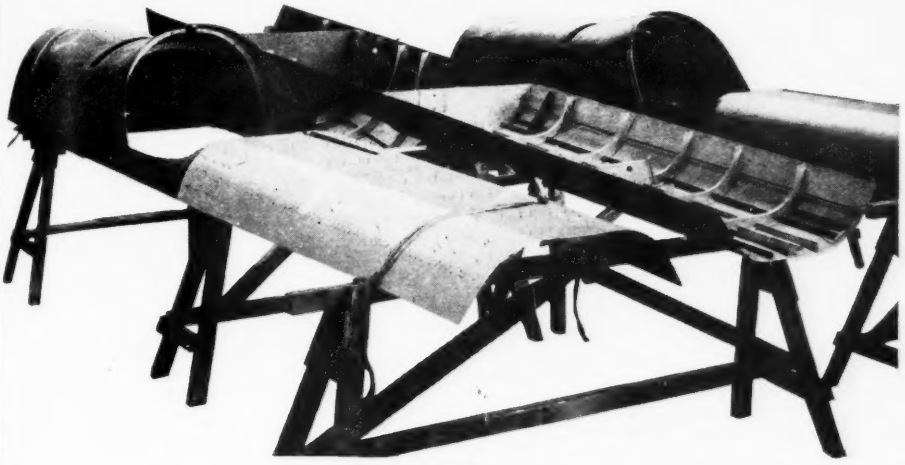

Fig. 8.
Hampden rear fuselage top portions.

CORRECT DETAILS

The curtailing of work in the larger and final jigs necessarily emphasises the need for accurate tooling of the details. The policy of Handley Page Limited is, and has been for quite a number of years, to have every hole on the drawing drilled in the template and every hole in the detail from the template. This ensures the fulfilment of the required condition of no drilling during assembly, with consequent saving of valuable man-hours in assembly jigs. Errors in matching up to form assemblies will arise, but these are exceptional, and readily put right by correction of the templates.

Full-scale lofting and the transfer of dimensions to templates by mechanical methods of reproduction are described more fully below, and become more and more an indispensable aid to securing accuracy and

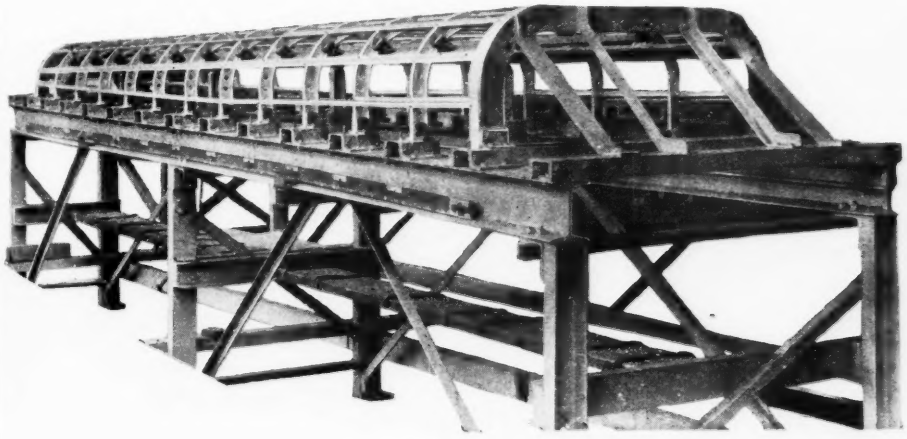

Fig. 9.
Hampden rear boom side in jig.

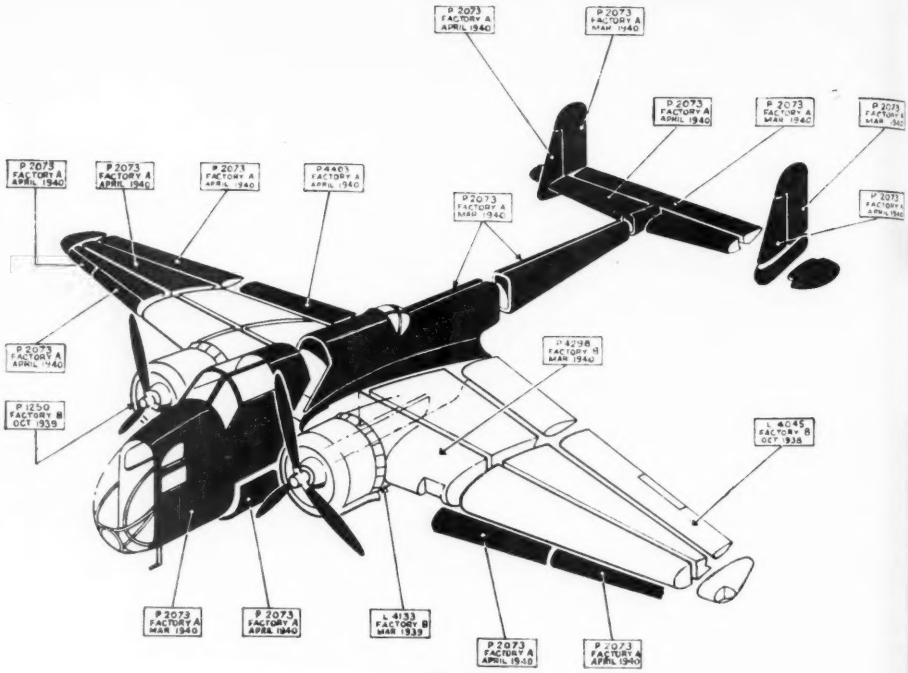
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Fig. 10.
Hampden interchangeability.

This Hampden was assembled without adjustment by an aircraft repair company from repaired components taken from salvaged Hampdens manufactured by two different factories between 1938 and 1940. Factory A shown black; factory B shown white.

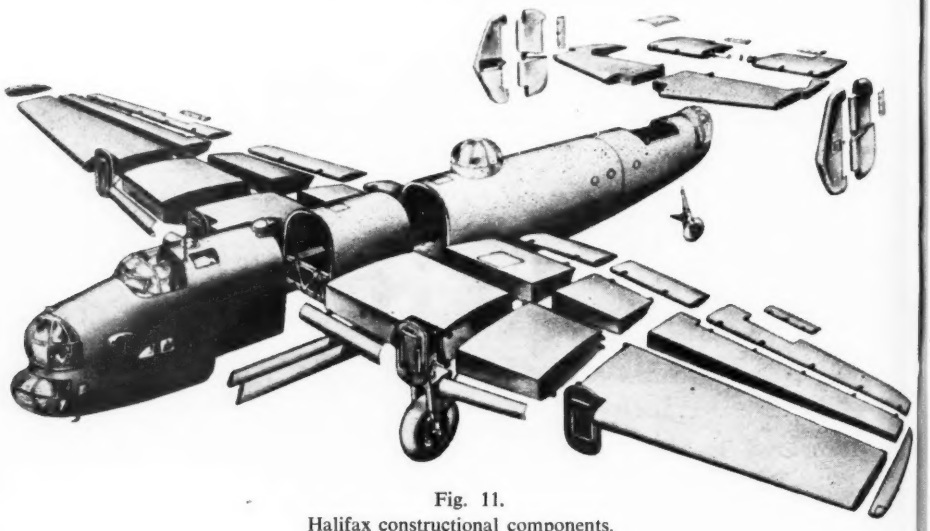


Fig. 11.
Halifax constructional components.

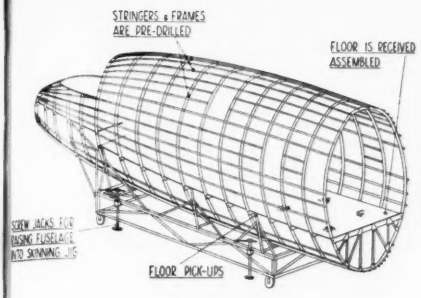

STRINGERS & FRAMES ARE PRE-DRILLED
FLOOR IS RECEIVED ASSEMBLED
SCREW JACKS FOR RAISING FUSELAGE INTO SKINNING JIG
FLOOR PICK-UPS

Fig. 12.
Hastings front fuselage assembly.

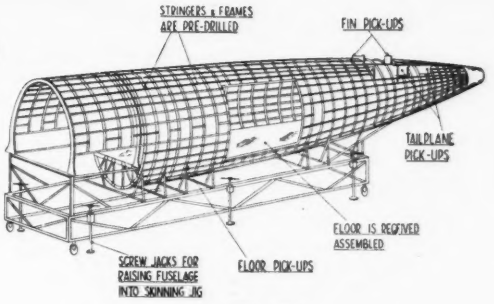


Fig. 13.
Hastings rear fuselage assembly.

interchangeability in detail part production. Reduction in the number of detail parts and the making of larger parts in an aircraft design, combining several details previously made separately has followed from the use of mechanical methods of forming. This increase in size of parts has simplified the sub-assemblies, and the obtaining of rigidity by formation pressing has effected great savings in man-hours, material, and component weight. Thus stiffening flutes, depressions and flanged lightening holes, can be formed simultaneously, and replace riveted angles, and so forth. The pressing is free from draw or hammer marks.

Fig. 14.
Hastings intermediate plane assembly.

Some typical examples of rubber press production are given in the next illustrations.

Figure 18 shows typical plain and lipped formation. Fig. 19 shows a typical rubber press former for producing flanges forward in opposite directions in two operations. The tool is known as a turn-over type.

It can be concluded that the most important feature of the rubber die press is that the number of parts per aircraft can be considerably reduced by:—

(*a*) Increasing the size of parts where possible, thus simplifying sub-assemblies.

(*b*) Obtaining rigidity by deformation, which presents saving in man-hours, material and components weight.

In order that these advantages can be utilised to the full, it is essential for the Drawing Office to be conversant with the

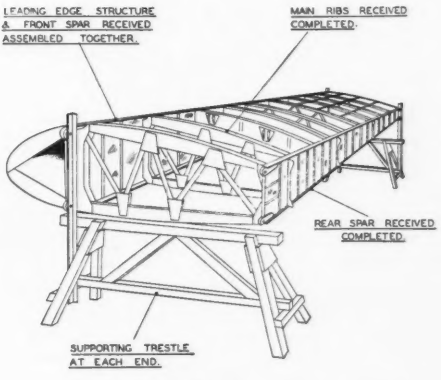

LEADING EDGE STRUCTURE & FRONT SPAR RECEIVED ASSEMBLED TOGETHER.
MAIN RIBS RECEIVED COMPLETED.
REAR SPAR RECEIVED COMPLETED.
SUPPORTING TRESTLE AT EACH END.

Fig. 15.
Hastings pre-assembly of outer plane, port and starboard.

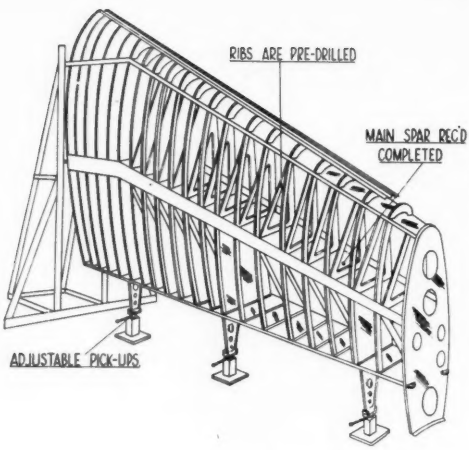


Fig. 16.
Hastings tailplane assembly.

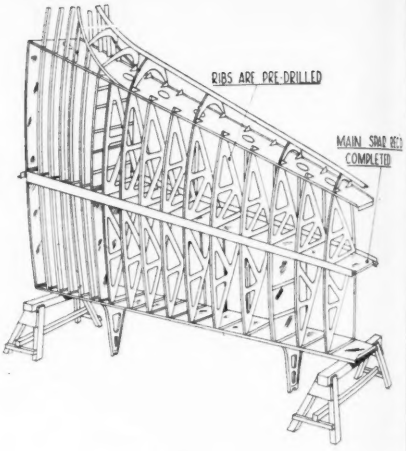


Fig. 17.
Hastings fin assembly.

technique. By means of process sheets, the Drawing Office is clearly notified of the limitations of the process and the tooling methods and requirements for economic operating. Fig. 20 is a replica of a typical process sheet and depicts a correct and incorrect position for a tooling hole, the type of pin used and a table of pin dimensions covering the range of diameters in use.

The routing machine can be used with advantage to finish off and trim pressings to their final shape. A typical component "window frame pressing" is shown in Fig. 21. The lip on the inside has to be removed from the inner flange, while the outer flange has to be trimmed to size and shape. The pressing is held in a fixture and the phenol template is placed over it. When trimming the inner flange, the template controls the depth of cut as well as the contour. In Fig. 22 the cutter, guide bush, and template are shown in relation to the component. This method of trimming pressings is now extensively used in the production of Hermes and Hastings.

The use of the rubber press has not only made for economy in production, but has also improved the general detail design. With its mechanical moulding effect, it has kept the hand method of working Alclad sheet, which is necessary to make the material flow properly to the required shape, but allows simpler and lighter wooden, or Jabroc, forming tools to be used, and larger details made with all the flutes included in the parts. The size of the rubber press tool is only restricted by the platen area of the press. An 8,000 ton press is used which gives a maximum pressure of $1\frac{1}{2}$ tons per sq. in. over a platen 9 ft. × 4 ft. with a 10 in. thick rubber pad which allows a maximum penetration, or draw depth, of $3\frac{1}{2}$ in.

STRETCHING PRESS PRODUCTION

The stretching press offers process methods alternative, as well as additional to, the rubber press. It permits forming of drawn or rolled sections with simple or compound contour, and can be done quickly and cheaply without elaborate or costly machinery.

These types of simple hydraulic stretch form machines were constructed with the use of redundant flap and bomb door jacks. Fig. 23 illustrates a horizontal type of machine with one vice connected to three hydraulic jacks at one end of the machine bed, and the other vice adjustable over the length of the bed. The direction of pull is horizontal. Work having shallow contours is produced on this machine.

Figure 24 shows a machine used for deep contours. The bed of the machine rests on

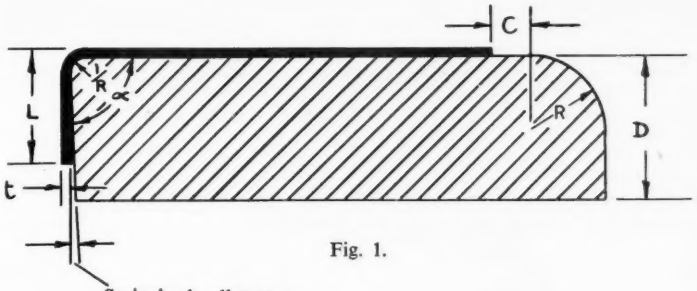


Fig. 1.

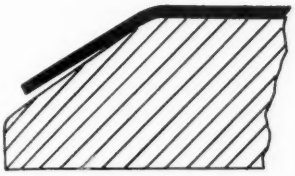


Fig. 2.

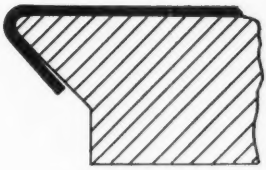


Fig. 3.

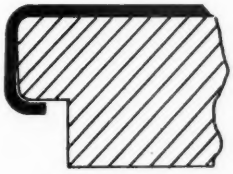


Fig. 4.

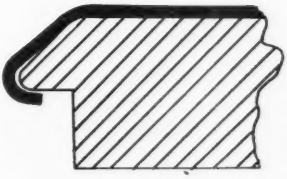


Fig. 5.

Fig. 6.

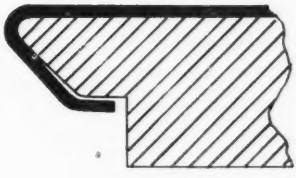


Fig. 7.

Figs. 1 - 14 (see also P.S. 10) are standard tooling sections for simple flanging of:—

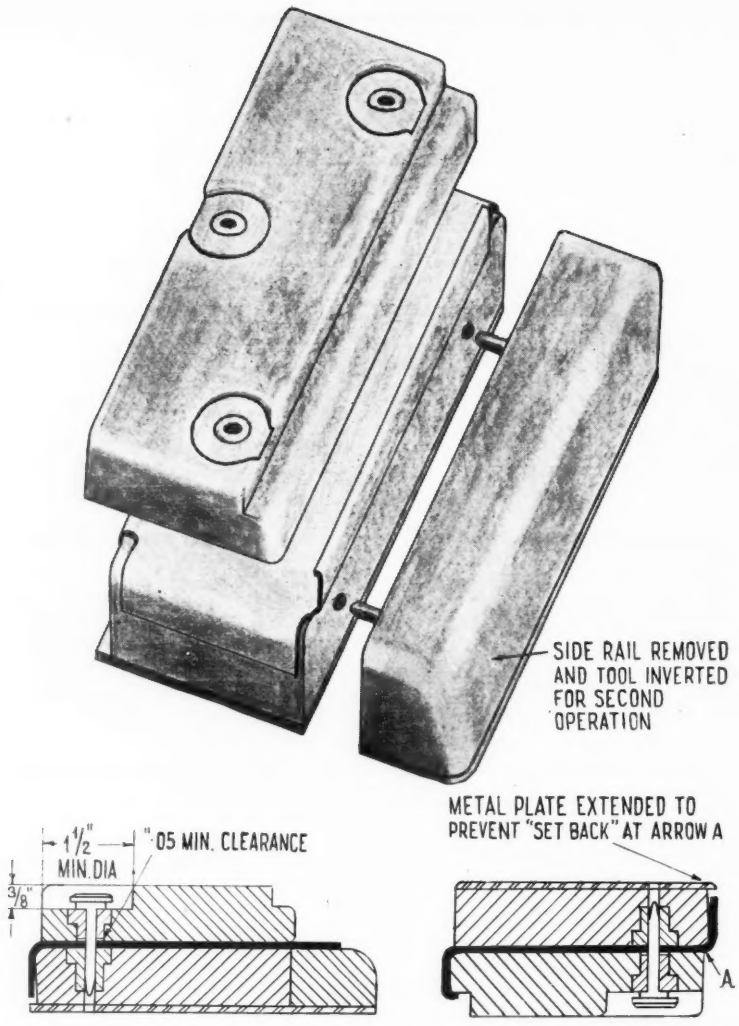
Straight flanges
Shrink flanges } For sizes see P.S.12.
Stretch flanges }

For dimensions L and t as stated on detail drawings, D is equal to:—

$L-t+\frac{1}{32}$ min.	22 S.W.G. – 18 S.W.G.
$L-t+\frac{3}{32}$ min.	16 S.W.G. – 12 S.W.G.
$L-t+\frac{1}{4}$ min.	10 S.W.G. – 6 S.W.G.

To avoid excessive wear on the rubber pad rad. R is to be as large as possible, preferably $\frac{1}{2}$ in.
For springback allowance see P.S.8.

Fig. 18.
Standard rubber press tooling, plain and lipped flanges (P.S.9).



Method is also applicable to forming plain and lipped, acute and obtuse angled flanges.

Where pressings have acute and obtuse flanges it is advisable to form the acute flange in the first operation.

Ensures economy in tooling and manufacturing.

Fig. 19.

Standard rubber press tooling, reverse flanging.

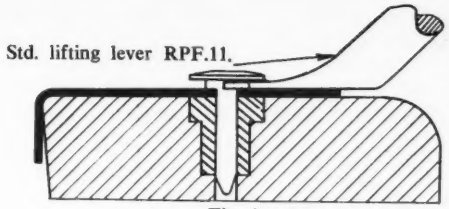


Fig. 1.

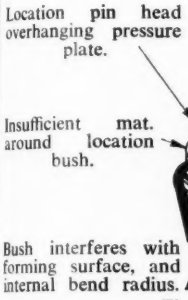

Location pin head overhanging pressure plate.
Insufficient mat. around location bush.
Bush interferes with forming surface, and internal bend radius.

Fig. 2 (incorrect).

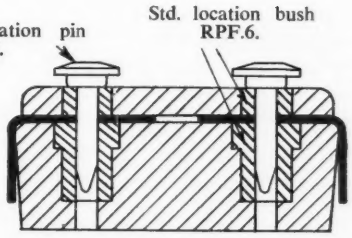
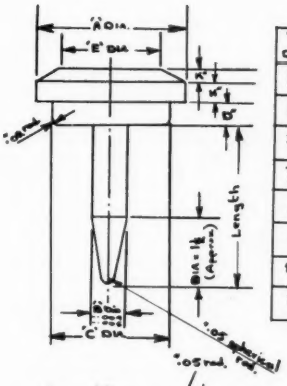
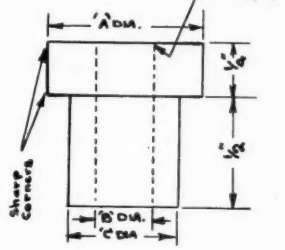


Fig. 3 (correct).

Figs. 2 and 3 illustrate difficulties incurred by close proximity of location holes and internal heel line.



'B' DIA	'A' DIA	'C' DIA	'E' DIA	'D'	'H'	'K'
1/8"	1/2"	1/4"	3/16"	.125	1/16"	.05
5/32"	1/2"	1/4"	3/16"	.125	1/16"	.05
3/16"	5/8"	3/8"	5/16"	.125	1/16"	.05
7/32"	5/8"	3/8"	7/16"	.125	3/32"	.05
1/4"	3/4"	9/16"	1/2"	.125	1/8"	.08
5/16"	7/8"	5/8"	1/2"	.125	1/8"	.08
23/64"	7/8"	5/8"	1/2"	.125	1/8"	.08
3/8"	1"	3/4"	5/8"	.125	1/8"	.08



'B' DIA		'A' DIA.	'C' DIA.
NOMINAL	DRILL		
1/8"	30	5/8"	3/8"
5/32"	21	5/8"	3/8"
3/16"	12	11/16"	7/16"
7/32"	2	11/16"	7/16"
1/4"	F	3/4"	1/2"
5/16"	O	13/16"	9/16"
23/64"	U	7/8"	5/8"
3/8"	V	7/8"	5/8"

Fig. 20.
Standard rubber press tooling, standard tools.

the floor, has three jacks fixed at one end and three more jacks at the other end, adjustable over the length of the bed. Each set of jacks is pivoted to give a tangential pull on any contour. Three adjustable platforms, which support the form block, can be moved to any position along the machine bed.

Figure 25 illustrates the type of machine used for forming deep angle and channel sections. This type of work presents some difficulty, as trouble is experienced with wrinkling on the vertical face. To overcome the problem of wrinkling, the jacks exert an upward thrust on the form block while the section is being stretched with the aid of the horizontal jacks. A typical section of the work formed on this machine can be seen at the top right corner.

Form blocks used for stretch-forming operations fall into two categories, those with, and those without, top blocks. Sections of the type shown in the top view, Fig. 26, do not need top blocks. Sections of the type shown in the bottom view need the use of form blocks, as there is a tendency for the section to "creep" at the corners and collapse. In all stretch-forming operations the application of grease to the form blocks assists the operation and ensures a more uniform stretch throughout the section.

Stretch-forming of skin panels needs careful consideration. This process can be very satisfactory if the expense of tooling is justified. It is not intended to give a detailed description of the processes involved but, for those interested, a descriptive article was given in *Aircraft Production*, May 1948, by H. J. Dowsett.

EQUIPMENT ASSEMBLY OUTSIDE THE CONSTRUCTIONAL JIGS

So far consideration has been given to detail part manufacture and assembly of major units in jigs. There remains a similar problem for the manufacture and assembly of the units which form part of the aircraft services, such as the piping or electrics. Such units are used in ever-increasing quantities and their preparation and installation may occupy an appreciable amount of the time allotted for the whole aircraft. Efficient jigging and the use of special tools speeds production, by reducing manufacturing difficulties, and providing a steady flow of details to the assembly lines, as well as ensuring interchangeability, which is the essence of an efficient spares service. As an example of the type of appliance envisaged, a simple form of pipe bending machine may be cited.

PIPE BENDING

Pipes up to $\frac{1}{2}$ in. outside diameter with a minimum bend radius of approximately four times the pipe diameter, can generally be formed on a hand machine without signs of wrinkle or collapse, irrespective of gauge or material; but pipes of $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. diameter present a different problem, since, to avoid wrinkle or collapse, they must be supported internally. The old method of loading the

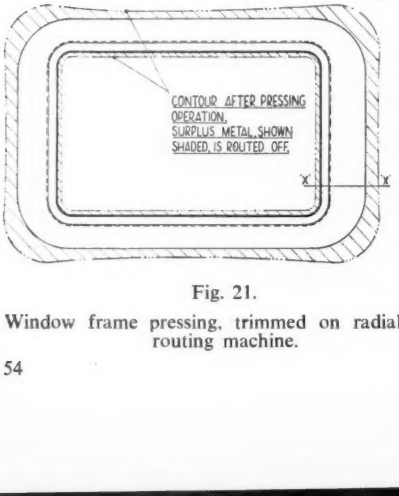


Fig. 21.

Window frame pressing, trimmed on radial arm routing machine.

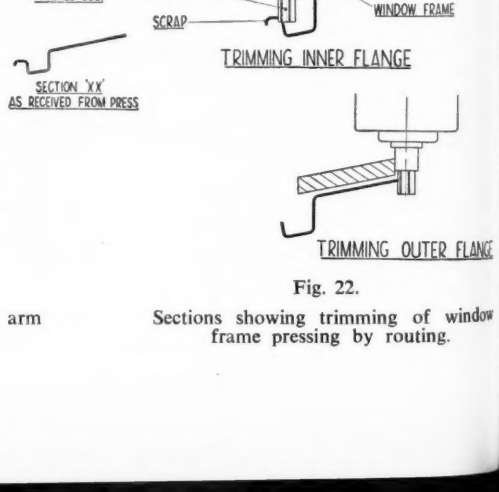


Fig. 22.

Sections showing trimming of window frame pressing by routing.

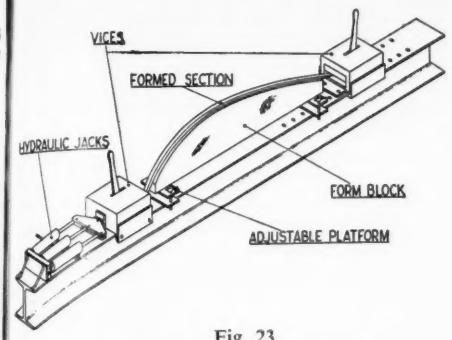


Fig. 23.
Hydraulic stretch-form machine.

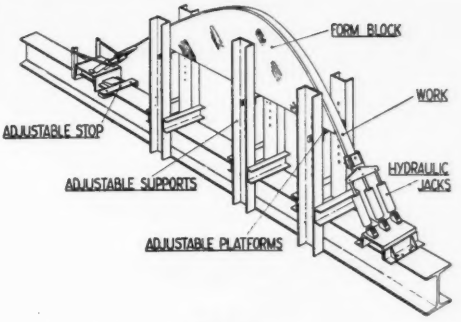


Fig. 24.
Stretch form machine for deep contours.

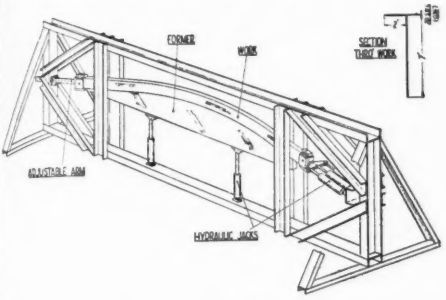


Fig. 25.
Stretch form machine for deep angles and channels.

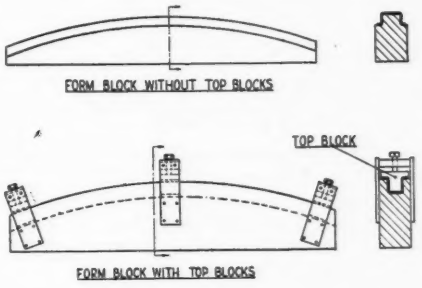


Fig. 26.
Stretch forming—typical form blocks.

pipes with resin before bending, was both long and costly, and this led the Handley Page works staff to design and produce a pipe bender (as shown in Figs. 27 and 28) in which the essential principle was the use of a metallic ball, instead of plastic loading.

The machine, shown generally in Fig. 29, is power-operated, and includes a ball attached to a mandrel located inside the pipe. The pipe and former are rotated while the ball and mandrel remain in the set position and provide support where the bend takes place. The ball and mandrel are made .008 in. smaller in diameter than the nominal inside diameter of the pipe to be formed. The pipe former and clamp are carried on a main spindle rotated by an electric motor through a worm drive, in the manner shown. The sliding support bar is fixed to the machine bed. A rear collet head traverses the bed, gripping the pipe, and moves with it; this head is used to set one bend in relation to a previous bend, in pipes where bends occur in more than one plane. The ball extractor bar extends the length of the machine, passes through the rear collet and at the far end is attached to an air cylinder, which extracts the ball after each bend has been completed and returns it to its correct position to start the next bend.

The machine is simple to operate and, after two or three hours' instruction, can be placed in charge of an unskilled hand. The pipe is threaded on the mandrel, gripped in the rear collet and the pipe clamp secured. The sliding bar is then set in position to prevent the pipe springing while bending is taking place. The bend is formed by rotating the pipe and former while the operator reads the protractor on the machine to check the amount of rotation required. On completion of the bend, the ball and mandrel are extracted, the pipe clamp removed, and the former and clamp returned to their original position. The pipe is drawn forward and the collet bush revolved to the correct angle for any subsequent bend in the pipe.

Full economy in the use of the machine is

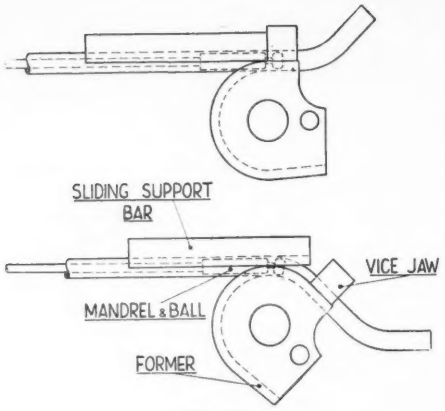


Fig. 27.
Pipe bending machine, showing principles of operation.

best achieved by standardising the bend radii for pipes of the same size, and a minimum figure of $2\frac{1}{2}$ times the pipe diameter has proved satisfactory.

ELECTRICAL INSTALLATION

In modern aircraft the installation of the services may be a major problem and for the Hastings the electrical installation received its due attention. It is an earth return system employing cables formed into looms on long boards used for measuring and assembly. The cables are enclosed in polyvinyl chloride sleeves through which they are drawn by hand winches. The ferrules on the cable ends are crimped by a tool of standard pattern, but operated with compressed air. Production is expedited by working concurrently on five sets of looms. The completed looms are lashed and labelled and are then ready for installation in the aircraft. To ensure accurate positioning the looms are marked to coincide with a datum frame of the fuselage.

MECHANICAL PROCESSES OF REPRODUCTION

Any process by which marking off or setting out can be reduced or eliminated from works' practice, reduces the possibility of error in reproduction, and thus any further scheme which restricts expensive work on the jig borer is a direct aid to economy in both time and money.

The introduction of photo lofting is one such aid. By its means not only production, but even prototype aircraft and small quantity production can be placed on a more economical foundation. Photo lofting can be used not only for plate work, but also in the machine shop, where it can be adapted for the drilling of spar booms, longerons and various machined fittings, obviating the need for costly drill jigs in many instances. Its practical application was further developed by the use of a centrescope. This

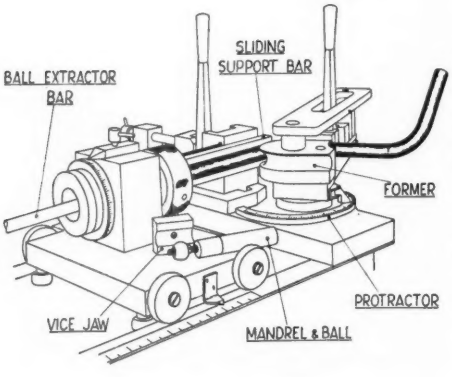


Fig. 28.
Pipe bending machine, showing bending head.

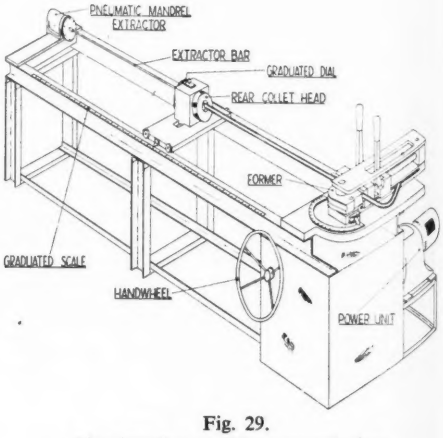


Fig. 29.
Pipe bending machine, general view.

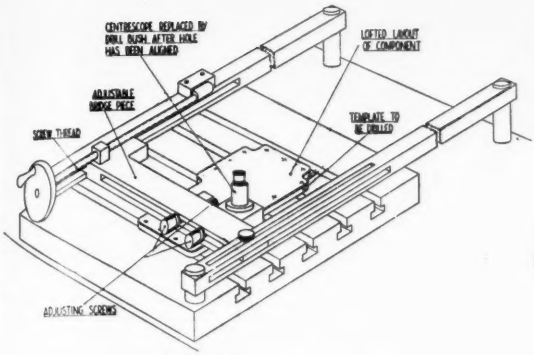

CENTRESCOPE REPLACED BY DRILL BUSH AFTER HOLE HAS BEEN ALIGNED
LOFTED LAYOUT OF COMPONENT
ADJUSTABLE BRIDGE PIECE
SCREW THREAD
TEMPLATE TO BE DRILLED
ADJUSTING SCREWS

Fig. 30.
Centrescope used in producing drilling templates from lofted layouts.

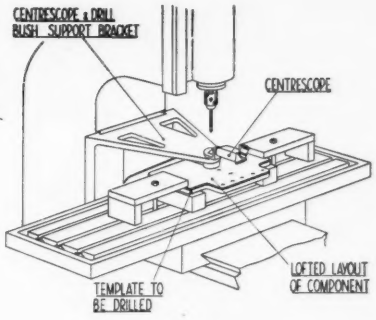


Fig. 31.
Production of drilling templates on milling machine using lofted layouts and centrescope.

instrument was designed for use on a radial drilling machine, as shown in Fig. 30, which can take sheets 8 ft. × 4 ft. For the sake of clarity the radial arm drill has been omitted. The figure shows the lofted reproduction over a phenol template on the table. A jigometer capable of traversing in two directions was designed to house the centrescope. After aligning the square lines of the loft layout through the centrescope, the jigometer is locked, the centrescope removed, drill bush inserted in its place and the hole drilled.

A similar adaptation of the centrescope on a vertical milling machine appears in Fig. 31. The only variation is that the work moves in this instance and the centrescope is fixed.

As previously emphasised, the reduction of tooling cost must always be paramount. For large quantities the foregoing methods are satisfactory but for smaller quantities the cost can be reduced if the phenol template is omitted. For example, on the Hermes IV the photo loft reproduction is clamped to five or six pieces of sheet which

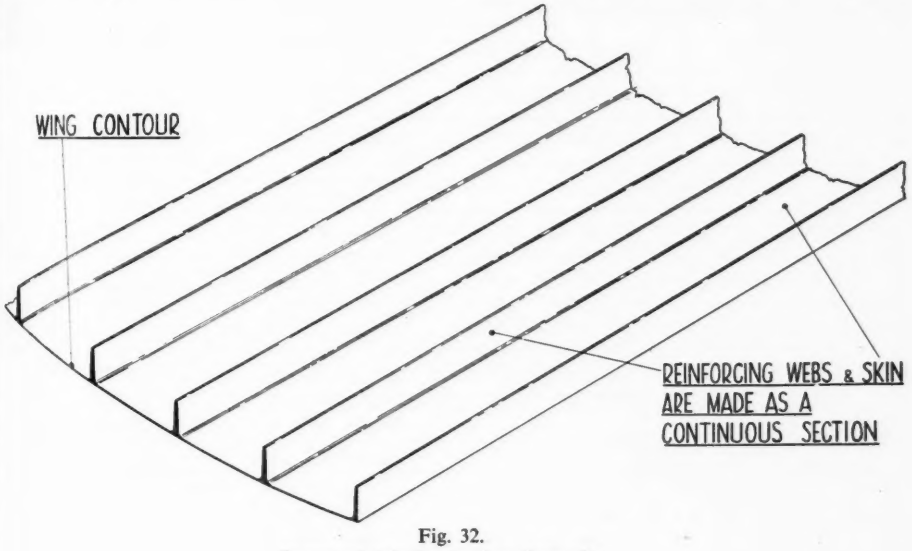


Fig. 32.
Suggested skin for laminar flow wing

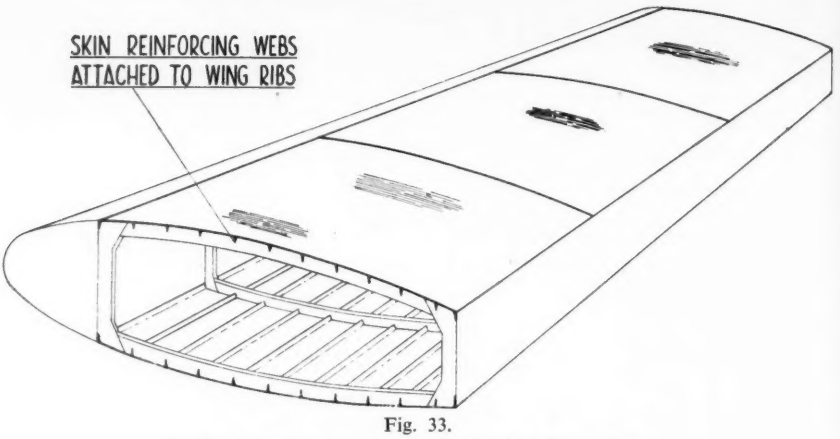


Fig. 33.
Application of suggested skin for laminar flow wing.

would finally make the required details and it is drilled through the centrescope method. The sheets, riveted together before the clamps are removed, make a thickness of 5/16 in. to $\frac{3}{8}$ in. The first batch of five or six details takes the place of the phenol template, through which the remainder of the batch of details are drilled. The reproduction is then filed to the size and shape of the detail and becomes the routing template for the batch.

LOOKING TO THE FUTURE

From a review of the production methods of the past and a survey of those in use on current aircraft, one naturally hopes to glean an insight into production development of the future. With a stable commodity in constant demand improved methods of production are evolved naturally, since future conditions can reasonably be foreseen. But with an ever-developing vehicle such as an aircraft, those happy conditions can hardly be expected. Aerodynamic research and the evolutions of unorthodox power units inspire the scientists to produce new materials and the production engineer finds himself faced with problems of a new type calling for a new approach and the adoption of new methods.

Already we are on the threshold of an age of adhesives and plastics, the sticking together of parts made from metals and non-metals and, can foresee the time when large aerofoil components may be composed of single plastic mouldings.

Future tendencies in design suggest ever greater speed and, as the supersonic range becomes commonplace, more and more emphasis will be placed on the quality and finish of aerofoils, until a surface permitting laminar flow conditions is economically produced.

The use of plastics solves some problems but creates others. Plastics can produce the desired finish and they lend themselves to sandwich construction, the layers of which are arranged in the direction of maximum stress in the individual components. Or wing skins and stringers might possibly be rolled out as one unit, as shown in Figs. 32 and 33, and so permit of a perfectly smooth surface without rivet head depressions.

Design work is simplified by the use of these newer aids but the initial stages of production may suffer in the period of transition to new conditions in the shops. For the prime mover of all production—the workman—adapts himself but slowly to major changes, new methods and new plant.

As the use of new machinery dispenses with some of the craftsmanship of the past, so the quest for new products opens the door for skilled work of a new and different order. The opportunity for co-operation between all departments concerned with development was never greater, nor more vital, than it is to-day. With inspired leadership, the combined work of the scientist and designer, the production engineer and the workman, will be rewarded by the achievement of that real progress which all of us so earnestly seek.

DISCUSSION

A. Vines (Fairey Aviation Co. Ltd.): He had been very distressed to hear that Mr. Robinson had appendicitis for he had known him for a long time, and during the War had worried him for "bits and pieces."

He thought everyone in the Aircraft Industry was worried, for they were always faced with a complete series of unknowns. The people who designed spent most of their time over blank sheets of paper, worrying what they were to produce, and the people who produced the bits spent their time worrying *how* they were to produce them.

The main points brought out during the Lecture, he thought, were that time was an important factor and that co-operation between the design, works and tooling departments was vital. From that it was clear that unless the conception of the job started right it had no hope of getting anywhere, because no amount of work on it could possibly cure it once it had got too far. Most of the aircraft developed fell into two classes; they were either research jobs and it did not matter so long as they succeeded in making one, and the others were primarily designed for someone to make a profit out of building, and therefore the cost was vitally important.

Everybody since the War had been trying to build lighter and cheaper aeroplanes. It might be possible to produce cheaper aeroplanes if the "fiddling" about that went on in every factory could be eliminated. The final cost of the job was tied up with the rate-fixers, and the rate-fixers had trouble in putting a price on a job because at the beginning they did not know what the man who was making it was going to do. Usually it was not until they had built ten or more assemblies that they settled down and knew what they were going to do—and that number in present conditions might be the complete contract.

They had thought of a process whereby suitably trained personnel would be started off on the job at the beginning, from the time when the designs began. If the job were ever to be sorted out, it had to be sorted out in the design stage, because once a particular type was in production there was never time to make major alterations.

If they had the right type of person he could start when the component was being designed, study the design as it was being formulated, study the detail assembly of every bit as it was designed. He would then study the jig and evolve the necessary assembly jig required, and he would actually work on it with the fitters building the component. Having done that he would be in a position to instruct the production charge-hands (who would have to use it), being in a position to demonstrate how the job, as it was conceived by the designer, should be done.

This was only a suggestion. It was an interesting point, and they were working on those lines and had made a certain amount of progress.

Time was important. They had had a description of the rubber bolster which had revolutionised the production of detail parts; lofting had revolutionised the accuracy of the detail parts; so what they now had to do was to tie the conception of the job to the actual man who would produce it.

He had seen a fuselage in production which was built without any jigs whatsoever; every single part was drilled and it was put together like a piece of Meccano and riveted. Following along these lines in the building of Halifaxes, they had come to the point where they built the wing up and only put it in the jig to put on the closing panel. As a development from that, they built wings without jigs by just levelling them on the floor. If that sort of thing were thought about from the beginning sub-assemblies could be produced which in themselves were assembly jigs, which merely had to be levelled up on the floor to make perfectly satisfactory assemblies without any error. This showed that if you made good sub-assemblies you could make good assemblies without any jig, which was a development of what Handley Page Ltd. had done during the War.

D. L. Hollis Williams (Fairey Aviation Co. Ltd., *Fellow*): He was particularly interested in methods whereby production effort followed on from prototype development.

Listeners would probably notice the similarity between his remarks and those made by Mr. Vines, but this was not

surprising as they were both members of the same engineering team and therefore shared the same theories on the subject.

His experience over many years had been that much time and money could be wasted through the stages of design, prototype manufacture and production jigging and tooling following each other in series. There was a tendency for the experience obtained during prototype manufacture to be lost during the time taken up by flight development, before the placing of a production contract warrenting jigging and tooling. He had heard of one case where the whole production theme incorporated in the design had been so lost sight of, with the result that production times were never reduced to the figure originally planned.

The way to overcome this series of efforts was, in his opinion, to design the process for manufacture in parallel with the design of a new prototype aircraft, which must have the effect of shortening the time from initial conception to production aircraft becoming available.

The method of achieving this result was for the jig and tool design staff and process planners to work as a combined team, with the designing draughstmen and technicians. This would not mean the same expenditure of time and money as for a full production effort, straightforward items such as machining fixtures, etc., would not be considered at the prototype stage, but the method of component breakdown and jigging should be settled in the initial stage, so that prototype manufacture would be based on the actual system of jigging which would be finally used in production. The aim should be to not only build a prototype aircraft, but also the prototypes of production jigs.

This method of designing an aircraft, and the process by which it was built at the same time, was undergoing development and appeared to be extremely promising as a time-saving factor.

Sir Frederick Handley Page (Past President of the Society, *Fellow*): He felt they had listened to an excellent paper about some excellent machines! It was probably a natural reaction to look back over a period of years in aircraft production. It was extremely interesting to reflect on the way in which the emphasis had moved in the production of aircraft. In the very early days if a machine flew at all that was a great achievement. The way it was manufactured and designed was quite subsidiary.

Where in the old days aircraft were built as an item of research and then adapted for production, now it was necessary, right from the beginning not only to study the design, but also, how to produce that design. In other words from the start they had to study the exploded drawing of the components and tell the drawing office and the design departments, "It doesn't matter what you think the aeroplane has to be like, that is the way in which you have to make it." It saved a lot of trouble if that was firmly laid down at the beginning. From that they could proceed to the detail make up of components so that, until they put the final skin on, they did not need to put the aircraft component in a jig at all. If they remembered one of the illustrations of the Hastings they could see the fuselage with the formers—the circular hoops around it. It was interesting to see not only the way in which that conception was carried out but also how it might be developed. That stage he thought had been referred to by Mr. Vines when he said that the only kind of jig that he wanted was the floor, which was to be found in every aircraft factory. By doing that they would be reaching a stage when they could say they were putting thought into aeroplanes from the initial design to the point of flight.

They were always apt to think of production of aircraft as a great scientific achievement represented by a whole range of symbols, "supersonic," "Mach Nos.," and so on. But what it all boiled down to was that the effort put into it by the design, drafting, printing, flying and other staffs must always be such that the customer who took it paid a little more than what that effort called for, so that, vulgarly, the company made a profit. It was also interesting to know in that respect that in spite of all the scientific significance and appeal that there was about an aeroplane, the operations that were performed were, in fact, no different from those performed in a retail shop. Fortunately in a retail shop the purchasers did not have an attendant inspection department to pass the article before it was bought! Nor had they a technical costing department who were concerned as to whether the price was right or not, nor had they attendant accountants to determine whether the overheads of the shop were right. If they

considered an aircraft manufacturing company, it was the same as a shop but in reverse.

The element that the American manufacturer had put into production shops was sound and significant, namely that the shop operated to make a profit. Close liaison was wanted between the drawing office and the works, and a close liaison between both of them and a costing system and accounts. If it were considered in that light then freak machines would not be built that no one wanted to buy, because even the design office had some regard to the price that was going to be paid for the aircraft.

There was a great deal in the paper and he was only sorry that Mr. Robinson was not there to read it. Unfortunately a week or ten days before he had suddenly been struck down by appendicitis and had been operated on the next day.

Dr. H. Roxbee Cox (President; Chairman of the Meeting, *Fellow*): He thought that production of aircraft was a section of aeronautics to which they in the Society could with profit pay a great deal more attention. Aircraft construction was one of the most refined kinds of structural engineering. There were no more refined methods than those of an aeroplane works and to him it had always been remarkable that as aircraft design had progressed and had demanded a more and more complex structural method, the production engineers had always managed to keep up; despite the complexities introduced by the scientist and technician they had been able to produce their work as quickly as before.

From what they had heard the moral was plain, the designer and production engineer must collaborate from the earliest possible moment in the aeroplane to be made, and the designer had always to think of the way in which his design was to be produced.

S. Camm (Hawker Aircraft Ltd., *Fellow*) *contributed*: He was glad that the Lecturer emphasised the importance of weight saving, as there seemed to him to be a distinct danger of this being overlooked in these days of complicated aircraft. Mr. Robinson's remarks also seemed to be applied to the possibilities of weight saving on details, but his own experience was that the overall design of the aircraft could exercise a much greater influence. One aspect of this, was the difficulty of deciding how far the aerodynamic requirements could be pursued at the expense of weight.

Another method of weight saving not mentioned in the Paper was that available by resisting attempts to cheapen production by deleting certain machining operations; this applied particularly to those details formed by stampings.

In the early part of the Paper methods of reducing man-hours on assembly were listed. In this list items 1.2.1 and 1.2.5 were surely methods of reducing the time spent in a main jig and did not reduce the gross man-hours spent on assembly. Incidentally, the author stressed the importance of the breaking-down of assemblies and sub-assemblies so that the operations might be easier, but this could itself cause an increase of weight. A further point on this question of assembly times etc. concerned that of rate fixing. Surely this could have a most important effect on the man-hour question?

The Lecturer had pointed out the successful use of mechanical processes of reproduction, and while he agreed that there were undoubtedly cases where photographic or lithographic methods had been employed to advantage, nevertheless there had been a good deal of exaggerated propaganda as to these advantages.

S. G. Custance (Manager, Hayes Factories, The Fairey Aviation Co. Ltd., *Assoc. Fellow*) *contributed*: The Lecturer was quite correct in stating that avoidable weight was a costly luxury. As a matter of fact, one famous aircraft company put the weight, whatever the size, on each detail drawing, and a spot check was enforced by the Inspection Department. This method kept the total weight of the aircraft within the designer's ambition.

In his 38 years' experience, he had no recollection of dimensional sketches, but sketches in duplicate were issued for alterations only, one copy being issued to the shops and one kept in the D.O. in order to keep the master tracing up to date. As regards the emergence of production from hand methods—before and during the First World War the aircraft fitter was considered a skilled man, as he was given a blue print, expected to make his own templates, and a certain quantity of details off to test his templates. The templates were then handed to semi-skilled fitters for the follow-on orders.

In his opinion, the real skilled fitter was now extinct because, if you asked an aircraft fitter of to-day to make his own templates, as likely as not he would be unable to do the job and demand templates made by the tool room, or, if able to do the work, would demand tool fitter's rate.

The Lecturer discussed the time factor in connection with an aircraft being put into production; to-day's method whereby the Ministry of Supply put out tenders for new types of aircraft, and the manufacturer, when tendering, had to submit a price, had a tendency to speed up the prototype and, subsequently, the manufacture, in order that costs might be watched.

Then there was, as stated, the basic problem of aircraft—the manufacture of an article by methods capable of rapid expansion for large and efficient production and, at the same time, flexible enough for changes in design to be rapidly introduced. The Bristol Aeroplane Co. were outstanding on this problem during this last war, as most of their major components were made to be interchangeable or, if not strictly interchangeable, the jigging was such that it could be easily altered to accommodate any new design or simple construction.

Now that the Aircraft Industry was throttled by so many specifications, in order to assist production, designers and draughtsmen should make every effort to quote the use of as many alternative specifications as possible on drawings. This also applied to limits on dimensions. Draughtsmen should be instructed to use standard dimensions and should not, for example, call for a hole say, 1.255 or .55 or .63.

The training of apprentices was important and in his opinion, no apprentice should be allowed to enter the Drawing Office until the last year of his apprenticeship. It had always been his view that no draughtsman, especially when designing a machined item, should put on to paper a design which he could not produce himself, and should limit it as simply as possible. He did not agree with the Lecturer that promising apprentices should be attached to heads of departments and encouraged to use commonsense and tact; he considered this tended to make them lazy. Let them be trained the hard way. For example, become a leading hand, then a chargehand and, finally, a foreman or, perhaps, a manager, and so on.

When referring to the working of a team of designers and producers, the Lecturer stated that to achieve easy means of fabrication the decision must be made to have no drilling on assembly. He would like to point out here that practical experience showed that certain holes always had to be left out when delivering detail spares.

The Germans had a clever method of jigging, *i.e.* they used a type of jig that could be adjusted to suit various sizes of components. Aircraft jigging had improved immensely since the 1914-18 War. In those days, wood was used a lot and even concrete. To-day many firms checked their assembly jigs once a month to make sure that the pick-up points had not moved. Other firms numbered their jigs and a corresponding number was put on the component produced, in addition to the date of manufacture, thus enabling their Inspection Departments to tell, when a component failed to assemble, exactly which jig was at fault.

Did the Lecturer rely on the final result off the rubber bolster press, *i.e.* if the contours were accurate, as he had found by experience that all important contours had to be finally set on a setting block by hand or power press tool.

There was no doubt about the benefit the routing machine had been to the Industry. He remembered how, in the old days, the majority of the work now performed on the routing machine used to be filed or nibbled to hardened templates, a much longer and more tedious job.

W. O. Manning (Ministry of Supply, *Fellow*) *contributed*: While it was no doubt convenient for production to split the wings and tailplane on an aeroplane into several separate components, it must not be forgotten that the various joints necessary would add to the finished weight. In the Halifax there appeared to be eight mainplane joints and, say, three belonging to the tailplane, and the additional weight caused by these joints might easily be 400 lb. On the author's figure of £18 per lb. per year for revenue loss for excess weight, this figure of 400 lb. meant a loss of revenue of £72,000, if the life of the aeroplane be taken as ten years. Even then, the convenience of many joints might be worth this amount, but it required demonstration.

He was interested in the simple form of construction proposed by the author for

laminar flow wings. Was there any reason why this type of construction could not be used for normal aircraft, even if completely smooth wings were not obtained? It would provide a much simpler structure than that normally used, and might be much cheaper.

The author's reference to the importance of gauge accuracy in plates to avoid excess weight was important. He thought the Admiralty custom of fixing weight limits for plates of so much per square foot should be adopted, in addition to gauge checks. Weight estimation would be much more accurate if this were done, and the plate manufacturer would gain by not supplying his customers with unwanted metal.

N. E. Rowe (British European Airways, and Vice-President of the Society, *Fellow*) *contributed*: Certain implications of the Paper and Discussion were of great importance. The development of new production methods was clearly attracting increasing attention, and this was being given practical effect in the very best way, by starting with the design of the parts which had ultimately to be produced and bringing the ideas of the builders to bear while the design was still taking shape on the drawing board. This technique had, he gathered, been in use to varying degrees for some time, but both Mr. Vines and Mr. Hollis Williams spoke of a much closer integration between design and building staffs than had been attempted previously. Mr. Vines also spoke of simplified assembly jigs and fixtures. If, as a result of these efforts, a stage could be reached at which the tooling and jigging was so simple that it could be applied to the prototype, then a most important advance would have been achieved. It would be important to military aircraft because the prototypes could be relied on to give results in flight trials truly representative of later production; it would be even more important in civil aviation, where numbers built were small and great advantages in operating economy could accrue from cheap and simple tooling and the ability to use prototypes (if built) in the operating fleet after they had played their initial experimental role. He would like the views of the Lecturer on these possibilities.

S. P. Woodley (Vickers Armstrongs Ltd.,) *contributed*: The Paper represented a well-balanced treatise on the manufacture of large aircraft produced during the last war period. It represented a good cross-section of the problems met and solved by most of the manufacturers of large aircraft, and called for little detailed comment.

Nevertheless, in common with other and, indeed, most articles in the technical press, it suffered a serious disadvantage in describing the solutions to problems which did not have their parallel in aircraft being built to-day.

While all production engineers agreed that it was highly desirable to break down an aircraft into small sub-assemblies, severe penalties might be paid when adopting this to pressurised aircraft.

Further, in striving for a better surface finish, and a better structure weight, joints, particularly bolted joints, must be kept to a minimum and, with the thin sections in current use, riveted joints were almost impossible.

From another aspect the use of a large number of sub-assemblies must receive serious consideration. Present-day contracts were usually for a small number of aircraft which had to be built quickly and economically.

There was seldom time, or for that matter, money, to produce a large number of sub-assembly jigs which occupied a large floor area; further, the modern aircraft factory did not employ a large number of semi-skilled labour trained for one operation only. Therefore, to make the best use of the available skilled labour and floor space, it was frequently more economical to avoid the use of a large number of sub-assemblies.

On the subject of assembly jigs, particularly wing assembly jigs, the trend seemed to be a reversion to the original method, that of building wings in the horizontal plane. This was made necessary by the use of large size, thick gauge skin plates, secured to the main structure by large diameter rivets, making handling and positioning a difficult operation in the vertical plane.

The thick plates themselves presented a problem in forming. The required shape was usually too shallow to stretch, the plate too big to form on a press or drop hammer, and the plate too thick to just fall into shape. The only possible method at the moment, for single curvatures at any rate, was to use power rolls of the size usually found in shipyards.

The problem of using large diameter rivets in confined spaces was causing considerable difficulty. The use of hot rivets had been considered, and research into materials and methods of heating were worthy of attention. Similarly the question of rivet-head finishing presented extreme difficulty. Should the hole be accurately reamed and countersunk and close tolerance rivets used, or should the heads be machined after riveting? Both methods required investigation, each needing specialised equipment yet to be fully developed.

Control surfaces represented another extreme. To avoid difficulties of mass balance, control surfaces required to be made as light as possible, and were usually constructed of extremely light gauge material. Surface finish was, of course, of utmost importance, and entirely new methods of manufacture were required.

Another manufacturing process causing some difficulty was that of bending heavy section wing booms in double heat-treatment light alloy. Few aircraft manufacturers had the requisite plant for this type of operation and, in considering the purchase and installation, guidance would indeed be welcome.

The possibility of using high tensile steel spars, requiring totally different manufacturing equipment, was facing the manufacturers of small, high speed aircraft, introducing a further production problem.

These few points represented some current problems met in production engineering, and were a plea for papers and articles which would give guidance on to-day's and, probably, to-morrow's problems, not as most frequently happened, information which was completely out of date when presented.

REPLIES TO THE DISCUSSION

Mr. SMITH: As no questions had been asked, or criticisms raised, there did not seem to be much to which he could reply, but the suggestion of Mr. Vines and Mr. Hollis Williams concerning an individual, or individuals, to work with the designers and draughtsmen was somewhat similar to an idea they had in view at present, but it would be an extension of existing arrangements. Someone would be appointed to work from the inception with a view to having the knowledge to train the people who would make the machine. So it looked as though great minds did think alike!

MR. ROBINSON'S WRITTEN REPLY

Mr. Vines: The close integration proposed between the design and trained personnel from the works was, in fact, in operation in his own company, and had been for quite a number of years.

To attempt to build wings or other components without a final assembly jig would be to make a very courageous decision. The operations suggested were practical and possible, but the component had no guarantee of alignment or interchangeability. Manufacturing the most simple jigs appeared to be the surest way of meeting all requirements.

Mr. Hollis Williams: That the closest liaison be maintained between design and works was all important. It was as a unified team that the best results were achieved.

The main structural design for a prototype should be fundamentally designed for a production repeat order. This permitted the assembly jigs and fixtures made for the prototype to be used for the repeat machines, should the prototype aircraft satisfy the design specification.

Mr. Camm: If the remarks on weight saving did not convey that the saving of weight on detail equally applied to machine parts, it was indeed intended. If production departments became seriously weight-conscious, the overall weight of the aircraft should come very close to the estimated weight calculated by the design department and so permit a degree of latitude for aerodynamic consideration.

The two methods of assembly suggested to reduce assembly man-hours, he agreed, did reduce the time spent in main assembly jigs, but the same methods permitted labour to be more gainfully employed at ground level, and distributed more economically, thus saving the time of climbing up and down the main jigs, or in and out of components.

The breaking-down of the aircraft into components introduced a penalty in weight

which design departments must, of necessity, accept because of the nature and uses of the aircraft, but if the component were further broken down as suggested, there need be no cause to increase the weight if the breakdown were carefully studied.

It could only be reiterated that, in his company, they had used mechanical processes of reproduction very successfully, and had no doubt that the limit had not yet been reached.

Mr. Custance: As the drawing carried all other information for the manufacture of a part, it should also have the weight of the part added.

In his company, this had been introduced and if the weight stated exceeded the tolerances permitted, the position was immediately reported to the design department.

The skilled fitter in the Aircraft Industry was not so much extinct as he was fast becoming overshadowed by the vast numbers of unskilled labour that had had to be introduced into the Industry to maintain the output of aircraft. It was by using the skilled labour to advantage in tool rooms and jig and tool departments that mechanical reproduction could best be assisted and simplified.

To encourage the drawing office to put on drawings as many alternative specifications as possible might confuse the materials and buying departments in the ordering and recordings of materials, and perhaps lead to stocks of various specifications being held in excess, consequently tying up a considerable amount of capital.

The training and placing of apprentices was, no doubt, a controversial subject. However, no matter which path was followed to attain managerial positions, commonsense and tact must be developed.

The rubber press had many advantages—it also had its limitations. Experience had proved that certain formations, if very accurate dimensions were to be maintained, needed finally dressing by hand on a block.

Mr. Manning: The question of root end fittings (joints) adding additional weight to the aircraft, was undoubtedly only too true, but in fairness to the design department one saw more clearly the past than the future. The old and heavy production of these joints was fast giving way to the latest and lighter design.

The proposed type of construction shown in Fig. 32 was essentially a raw material (sheet) manufacturer's problem, which required development and perhaps the need of financial assistance from the Industry or some research organisation.

Discussions were continually taking place between the aircraft firms and sheet manufacturers on the subject of producing sheets to very close tolerances. Advance in gauge accuracy had been most encouraging and the adoption of odd size gauges, together with the even size, would materially benefit the constructor and avoid unnecessary weight being built into the aircraft.

Mr. Rowe: The quality of aircraft built to-day was so exacting and the cost of jigs and fixtures could be so expensive that all aircraft, including prototypes, should (in his company they were) be built in truly representative jigs and fixtures of the simplest form, including the essential attachment points, while permitting the maximum degree of interchangeability.

Jigs and fixtures made for a prototype were used for repeat production machines, unless alterations were necessary because of aerodynamic requirements.

Mr. Woodley: The Paper endeavoured to cover as many developments and solutions to problems (in a given time) peculiar to his own company up to current production aircraft.

Without deviating from the method of breaking down the aircraft into small subassemblies, completed machines had been successfully pressurised. The only penalty that could be truly assessed was additional weight, due to the nature and quantity of the compound used.

The method of application of the compound was being developed to reduce the quantity used, with a corresponding saving in weight.

It could only be repeated that the practice of drilling every hole on the drawing into the detail part, eliminated the need for a large number of sub-assembly jigs. Sub-assemblies could be fabricated to an untold degree by this method, and brought to the final assembly stage prior to skinning, as seen in Figures 12 to 17.

Because of the size of the planes on large aircraft, it had always been more convenient to build them in the horizontal plane, due to the reasons stated. Tailplanes, which were of a size more easily handled, were built in vertical assembly jigs.

Without being too critical, problems such as thick plates and large size rivets should be faced in the initial design stage and considered with regard to existing plant and machinery, or the possibility of equipment already developed or easily procurable.

Control surfaces presented a challenge to production ingenuity. The perfect solution might ultimately be in a complete plastic moulding, or of plastic sandwich construction.

Raw material manufacturers could be of great assistance to problems of bending heavy extruded section if guidance were sought in the early stages of design. A similar problem in his own company was satisfactorily overcome by approach to the raw material manufacturers, who undertook and delivered the section to the formation required.

To sum up, a closer integration was required between production units of all aircraft firms, to discuss and interchange methods of manufacture on the factory floor, as distinct from papers and articles in the technical press which must, of necessity, be written in retrospect.

HELICOPTER HOVERING PERFORMANCE

by

C. M. BRITLAND, D.Ae., Grad.R.Ae.S.*

1. INTRODUCTION AND SUMMARY.

THE purpose of this paper is to indicate in a simple but quantitative form the primary aerodynamic factors governing the performance of a hovering helicopter (since the ability to hover is its prime virtue) and to show how the necessity to operate at a reasonable forward speed restricts that hovering performance. The paper is mainly of interest to potential users of helicopters and to others not actively engaged on helicopter design.

The standard power relationships for hovering flight, as developed by Glauert and Squire, are interpreted in graphical form, and the effect of forward flight in limiting the choice of aerodynamic and operational parameters, due to the onset of blade stalling and compressibility, is illustrated by means of boundaries on these graphs. The power requirements in forward flight are not considered.

2. NOTATION.

Dimensions of rotor

R = radius of rotor disc
$S = \pi R^2$ area of disc
$\sigma = \dfrac{\text{Blade area}}{\text{Disc area}}$ = solidity
θ_0 = mean blade angle
θ_1 = amplitude of oscillation of blade angle
β = coning angle

Motion

Ω = angular velocity of rotor
i = angle of incidence of rotor disc
χ = angle of tilt of shaft
τ = angle of climb

Forces

T = thrust
Q = torque
H = longitudinal force on rotor
W = weight of helicopter
W_b = weight of rotor blades
D = body drag
D_0 = body drag at 100 f.p.s. at sea level

Power

P_r = total power absorbed by rotor
P_i = induced power
P_p = blade profile power
$RHP = P_r/550$; total horse-power absorbed by rotor

Coefficients

u = velocity of flow through rotor disc parallel to axis
λ = disc flow ratio $(u/\Omega R)$
μ = tip speed ratio $(V \cos i/\Omega R)$
a = slope of lift curve of blade section
C_D = mean profile drag coefficient of blade element
$t_c = T/\sigma S \,.\, \rho \,.\, \Omega^2 R^2$
$h_c = H/\sigma S \,.\, \rho \,.\, \Omega^2 R^2$
$w_c = W/\sigma S \,.\, \rho \,.\, \Omega^2 R^2$
$d_c = d_0 (\mu^2 + \lambda^2) = D/\sigma S \,.\, \rho \,.\, \Omega^2 R^2$
$d_0 = D_0/10^4 \,.\, \rho_0 \,.\, \sigma S$
$\dfrac{W}{S}$ = disc loading
M_{AT} = local Mach number of advancing blade tip

3. POWER REQUIREMENTS IN HOVERING FLIGHT.

3.1. Nature of power requirements

In hovering flight the power used to overcome parasite drag is negligible, and the principal contributions to power consumption are:—

(*a*) Induced power P_i
(*b*) Blade profile power P_p
(*c*) Transmission and cooling power losses, power for torque compensation and so on.

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* Mr. Britland has been in the Aerodynamics Department at R.A.E. since 1944, first in the High Speed Tunnel and later in the Project Sections.

Item (*c*) is outside the scope of this paper, and all further reference will be to the "rotor horse-power" (R.H.P.) available at the rotor head. Present experience suggests that the ratio $\frac{RHP}{BHP}$ is of the order of 0.85 for the "Sikorsky configuration" in vertical flight, and of the order of 0.90 for a twin-rotor helicopter.

3.2. Induced power.

The induced power P_i is the power required to accelerate the mass of air entrained by the rotor system, and is the power which would be consumed by the equivalent "actuator disc."

Application of simple momentum theory[1] leads to the standard result that, in hovering flight,

$$P_i/W = \frac{1}{\sqrt{2}}\left(\frac{W/S}{\rho}\right)^{\frac{1}{2}} \quad . \quad (1)$$

The induced power is therefore independent of all rotor characteristics except the disc loading W/S. The induced power required to hover also increases with decrease of air density.

3.3. Blade profile power.

Blade profile power is the power required to overcome the torque arising from the profile drag of the rotor blades.

An approximate equation for profile power, derived from the work of Glauert and others, is that

$$P_p/W = (1/8)\rho C_D \sigma (S/W)\Omega^3 R^3 [1 + 3(\mu^2 + \lambda^2)] \quad . \quad . \quad . \quad . \quad (2a)$$

and for hovering flight, where $\mu = 0$ and λ is of the order of 0.1 or less, the term $3(\mu^2 + \lambda^2)$ can be neglected. It will therefore be assumed that

$$P_p/W = (1/8)\rho C_D \sigma (S/W)\Omega^3 R^3 \quad (2b)$$

The term C_D is normally taken as the mean profile drag coefficient of the blade section, over the range of angle of attack from zero lift to just before the stall.

Equations (2*a*) and (2*b*) show principally that the profile power increases rapidly with increase of rotor tip speed ΩR, and also increases in proportion to the blade area σS, as would be expected.

3.4. Rotor power.

The total power absorbed by the hovering rotor, hereinafter called rotor power, is the sum of the induced power and the blade profile power.

$$P_r/W = P_i/W + P_p/W \quad . \quad . \quad (3a)$$

and therefore

$$RHP/W = (P_i/W + P_p/W)/550 \quad (3b)$$

In practice the power consumption is somewhat higher than this because of losses at the blade roots and tips, rotational energy imparted to the slipstream, spanwise flow on the blades and other small items, but no allowance has been made for these losses in the accompanying figures.

4. LIFTING POWER IN HOVERING FLIGHT.

4.1. General.

The maximum weight which a rotor can support in hovering flight at a given altitude can be simply indicated by the maximum allowable value of rotor power loading, W/RHP lb. per rotor horse-power, as derived from equations (1), (2*b*) and (3*b*).

The maximum rotor power loading has been adopted as the most suitable performance parameter for the purposes of this paper, and its variation with the principal aerodynamic and operational parameters is illustrated in the figures.

4.2. Effect of altitude.

It is apparent from the equations of Section 3 that the power consumption is critically dependent upon air density and hence altitude. Since the induced power term is larger than the profile power term for the normal values of disc loading and tip speed, it follows that the total power consumption increases with increase of altitude.

A full appreciation of the effect of altitude on helicopter performance must include the altitude effect on engine power, and has therefore been omitted. Calculations and figures are all based on an assumed maximum hovering altitude and altitude for maximum speed of 5,000 ft. (I.C.A.N.) which is likely to cover the requirements of most European and naval operators for several years to come. It must be remembered that such helicopters will be capable of reaching much greater altitudes in forward flight.

4.3. Effect of aerodynamic and operational parameters.

Figures 1, 2 and 3 each depict the variation of W/RHP with disc loading for a range of rotational tip speeds. Comparison of Figs.1 and 2 shows the beneficial effect, from a lifting efficiency viewpoint, of a reduction in rotor solidity. Comparison of Figs. 2 and 3 shows the value of reducing the profile drag of the blades.

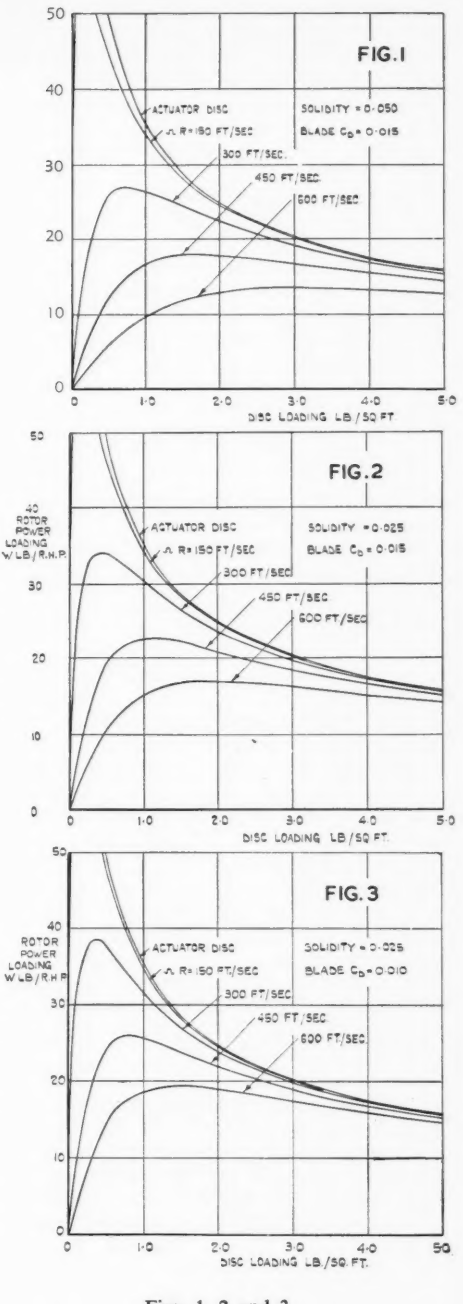
Present-day values of rotor solidity range from 0.08 to 0.03, and the value of 0.05 used in Fig. 1 is fairly representative. A solidity of 0.025, as assumed in Figs. 2 and 3, is likely to be almost the lowest that can be reached in three-blade rotors, bearing in mind the structural problems of blade design. Two-blade rotors could probably be built to a slightly lower solidity, but there are inherent vibration problems associated with two-blade rotors which are bound to hamper development.

The estimation of the mean drag coefficient applicable to rotor-blades undergoing cyclic feathering or flapping has not yet been put on a reliable basis, but again it is believed that the value $C_D = 0.015$ chosen for Figs. 1 and 2 is fairly representative of current achievement. Likewise, the reduction to $C_D = 0.010$ in Fig. 3 is an improvement which can reasonably be hoped for in the near future.

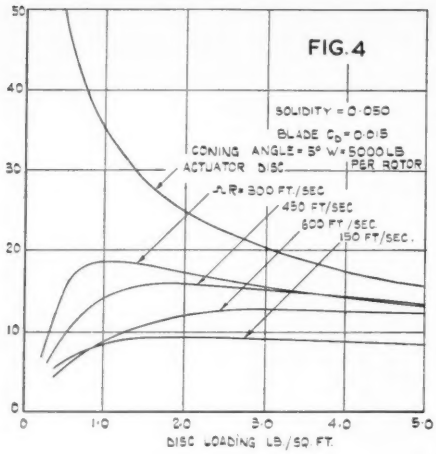
To summarise, therefore, the curves of Fig. 1 may be taken to represent present-day performance targets, Fig. 2 is the target for the next period of development and Fig. 3 approaches the limits to lifting performance which seem likely on the basis of present knowledge.

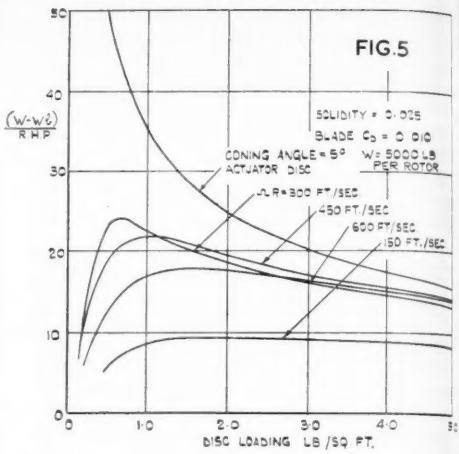
Comparison of these figures at a typical disc loading of, say, 3 lb./sq. ft. reveals at once that there is nothing startling to be gained by improvement of the aerodynamic design of rotors. The maximum theoretical load that could be sustained at 5,000 ft. is 20.3 lb. per rotor horse-power, while at a practical tip-speed of, say, 600 ft./sec. current practice as represented by Fig. 1 would give a lifting power of 13.5 lb./R.H.P. Even a 50 per cent. reduction in solidity and a 33 per cent. reduction in blade drag (Fig. 3) would still only give a lifting power of 17.4 lb./R.H.P.—a 29 per cent. improvement.

Figures 1, 2 and 3 all suggest that larger improvements are obtained at lower disc



Figs. 1, 2 and 3.
Lifting power in hovering flight at 5,000 ft.





Figs. 4 and 5.
Net lifting power in hovering flight at 5,000 ft. (Figs. 1 and 3 corrected for blade weight.)

loadings, but, as will now be shown, such conclusions are modified greatly when the weight of the rotor is taken into account.

4.4. Effect of rotor blade weight.

The weight of the rotor blades can be simply related to tip-speed, rotor-size, and coning angle if we assume a freely-flapping blade system, and it can be assumed that the corrections to lifting performance obtained on this assumption, in general, will be qualitatively applicable to feathering (non-flapping) blades.

Once again, only the order and nature of the blade weight correction is shown. The associated weight variations of the rotor head and parts of the transmission have been ignored, since they are of a more complicated nature and are "slow" variations compared with that of blade weight.

Assuming an untapered, untwisted blade of constant density, operating at constant lift coefficient from root to tip, it is simply shown that the centre of lift is at $0.75R$, the centre of gravity is at $0.5R$, and the centre of centrifugal force is at $0.67R$. Taking moments about the flapping hinge it follows that, in hovering flight,

$$\frac{W_b}{W} = \frac{1.5}{\cos^2\beta\left(1+\frac{\Omega^2R^2}{1.5gR}\sin\beta\right)} \qquad (4)$$

where β is the steady coning angle and W_b is the weight of the rotor blades.

In order to apply this relationship as a correction to Figs. 1, 2 or 3 it is necessary to assume a coning angle and the weight to be supported by a single rotor. Although the optimum coning angle may be greater than the values used in current designs, practical experience to date suggests that coning angles in excess of about 6° tend to give rise to roughness of operation in forward flight. It follows that blade weight is not always decided by strength and stiffness considerations. Extra weight may have to be "built-in" to maintain a practical coning angle, and the blade weight is sometimes increased to give high rotor kinetic energy for use in auto-rotative landings. The corrections have therefore been based on an assumed coning angle of 5° and an assumed helicopter weight per rotor of 5,000 lb. The value of (W_b/W) has been calculated for a range of tip speeds and disc loadings, and hence the net lifting power $(W-W_b)/RHP$. The effect of this correction on Figs. 1 and 3 is shown in Figs. 4 and 5, and it is seen

(*a*) that reduction in tip speed necessitates a large increase in blade weight to maintain the centrifugal force moment, with the result that there is an optimum net lifting power occurring at medium or high tip speeds, contrary to Figs. 1, 2 and 3, and

(*b*) that reduction of disc loading, by increasing the rotor diameter, also leads to relatively heavy blades thus greatly reducing the apparent benefits of low disc loadings indicated by Figs 1, 2 and 3.

It is clear, from the form of equation (4), that the effect of blade weight will be less significant if a larger coning angle can be adopted.

5. LIMITATIONS IMPOSED BY BLADE STALLING AND COMPRESSIBILITY

5.1. Statement of problem.

Periodic stalling of the rotor blades transmits roughness and vibration to the controls, and possibly to the complete aircraft. It is a basic design requirement, therefore, that the maximum angle of attack attained by any part of the blade shall not exceed the stalling angle of the blade section.

In forward flight stalling incidence is first reached on the retreating blade, where the mean pitch angle is increased by the cyclic pitch variation applied* to prevent rolling. The amplitude of this applied variation increases with increase of forward speed and therefore the permissible mean pitch angle must decrease with increase of forward speed. It is the mean pitch angle which determines the thrust obtainable from the rotor and, if this angle and the corresponding lift coefficient is specified, then for a rotor of given solidity there are obviously only certain combinations of disc loading and tip-speed which will provide a thrust equal to the resultant of weight and drag.

Now the disc loading remains virtually constant during flight and in general, since the engine will be giving full power both at the hovering ceiling and at maximum forward speed, the engine r.p.m. will be substantially the same in these two extreme flight conditions. Unless a practicable variable gear ratio is developed, it is clear that the combinations of disc-loading and tip-speed used in determining the hovering performance are limited by the requirement that the same combinations shall be capable of providing the required lift and forward thrust at a specified maximum speed without exceeding the blade stalling boundaries. Since the rotor thrust is required to balance the resultant of the weight and the total drag, it follows that the parasite drag of the helicopter has an effect upon these stalling boundaries which is, however, small.

It will be found that, for any given values of forward speed and tip-speed, there is an upper and a lower limiting value of disc loading at which the blade will be operating on the stalling boundary. The upper limit is the obvious case of designing to too high a blade loading. The lower limit is a mathematical boundary arising from the assumption, in the helicopter theory of Glauert and Squire, of untwisted blades. When the disc flow ratio (λ) is high this assumption leads to negative thrusts on the inboard blade sections and a correspondingly higher thrust is required from the tip sections. Hence a tip stall is eventually reached. This boundary does not affect helicopter design in practice, although it is related to the problem of designing a rotor which can be turned through 90° to act as a propeller in forward flight.

5.2. Derivation of stalling boundaries.

It will be assumed, on the basis of American flight tests and general aerofoil data, that the stalling angle of typical helicopter blade sections is 16° (0.28 rad.). To simplify the calculations it is also assumed that the section lift slope $a=6.0$ per radian, and that this slope is maintained up to the stalling angle.

If the mean pitch angle is θ_0, it has been shown by Glauert[2] that the amplitude θ_1 of the incidence variation required in translational flight to give zero rolling moment is given by

$$\theta_1=(8/3)\,\mu\,(\theta_0-3/4\lambda)/(1+3/2\mu^2) \qquad (5)$$

The maximum angle of attack attained by the blade is therefore

$$\theta_M=\theta_0+\theta_1=\theta_0 +(8/3)\,\mu\,(\theta_0-3/4\lambda)/(1+3/2\mu^2)=0.28 \qquad (6)$$

This equation applies to all conditions of steady flight. For level flight, using the relationships developed in ref. 3,

$$\tau=0 \text{ and } i=\chi$$

$\therefore$ $\tan i=\tan\chi$

i.e.

$$\lambda/\mu-\sigma t_c/\{2\mu\,(\mu^2+\lambda^2)^{\frac{1}{2}}\} =(h_c+d_c\cos i)/(t_c-d_c\sin i)$$

* Aerodynamically the freely-flapping blade system and the rigid blade system with applied cyclic feathering are equivalent in this respect. The downward-flapping retreating blade increases its effective angle of attack and vice versa.

or approximately

$$\lambda/\mu - \sigma t_c/\{2\mu(\mu^2+\lambda^2)^{\frac{1}{2}}\} = (h_c+d_c)/t_c \quad . \quad . \quad (7)$$

Solution of the simultaneous equations (6) and (7) gives two values of λ for each value of μ, and corresponding values of θ_0 and i.

Then, since

$$w_c = (t_c/\cos\chi) - d_c \tan\chi \quad . \quad (8)$$

and

$$W/S = w_c\sigma\rho\Omega^2R^2 \; . \quad . \quad (9)$$

the corresponding limiting values of disc loading can be evaluated.

The value of $d_c\{=d_c/(\mu^2+\lambda^2\}$ assumed in these calculations is 0.025, which represents a typical twin-tandem helicopter or a clean single-rotor design. The effect of doubling this parasite drag parameter is to reduce by about five per cent. the upper limiting disc loading.

The results of such stalling boundary calculations for

(*a*) $\sigma=0.050$, $C_D=0.015$, and

(*b*) $\sigma=0.025$, $C_D=0.015$ or 0.010.

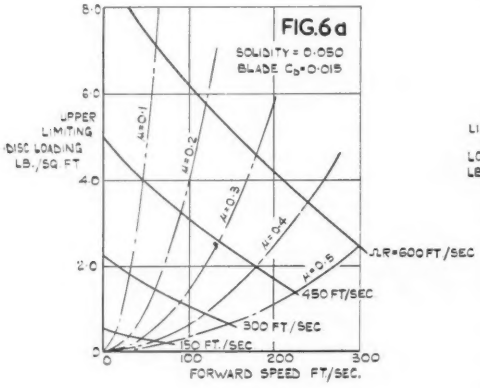
are shown in Figs. 6 and 7. The effect of reducing blade C_D from 0.015 to 0.010 is too small to be shown on these diagrams. It is clearly seen from these figures how the important upper limiting disc loading decreases almost linearly with increasing forward speed. It is also clear that use of low solidities necessitates high tip-speeds if the rotor is to be kept within reasonable dimensions.

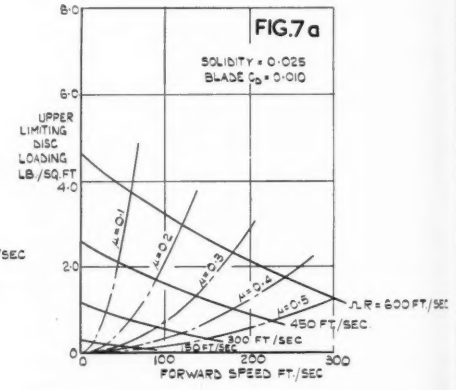
5.3. Compressibility and reverse flow boundaries.

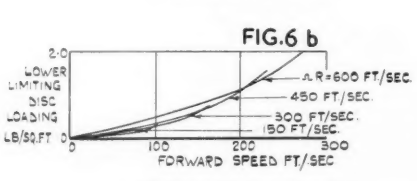
The employment of high tip-speeds introduces a further complication, since it is desirable to avoid compressibility phenomena occurring at the blade tips. The limitations imposed by this consideration naturally become more severe as the forward speed increases, adding a further relative velocity component to the advancing tip.

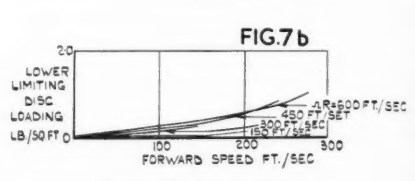
The precise compressibility boundary varies somewhat with the type and thickness ratio of the blade section employed, and the lift coefficient at the advancing tip. To indicate the order of the restrictions from this cause, it is assumed here that the Mach number on the advancing tip (M_{AT}) must at no time exceed 0.8.

Similarly, the employment of low tip-speeds raises the possibility that, in forward









Blade stalling angle = 16°.

Blade lift slope a = 6.0.

Figs. 6 and 7.

Disc loading limitations imposed by blade stalling. Effect of forward speed.

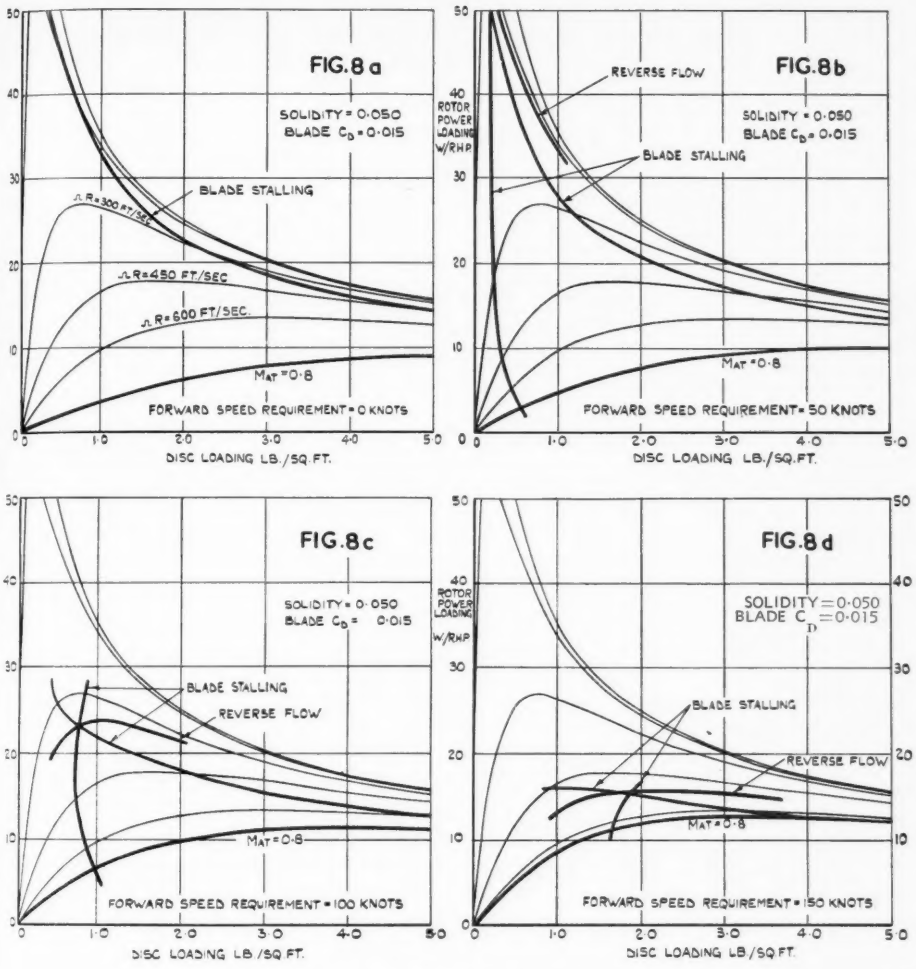


Fig. 8 *a, b, c, d.*
Blade stalling, compressibility, and reverse flow boundaries superimposed on Fig. 1.

flight, an excessive proportion of the retreating blade may be subject to reverse relative air flow, with consequent high power losses and roughness of operation, and a reduction in control of the blade flapping motion at that part of the disc. This problem seldom arises in practice, and so there is little experimental data available to show just how much reverse flow is tolerable. Glauert originally suggested that not more than the inner 50 per cent. of the retreating blade should experience reverse flow, and this suggestion is adhered to here. It implies that the rotational tip-speed shall never be less than twice the required forward speed.

6. APPLICATION OF BOUNDARIES TO CHARTS OF HOVERING PERFORMANCE (Figs. 8 and 9).

As explained in Section 4, the choice of aerodynamic and operational parameters to give optimum efficiency in hovering can only be made in the light of the maximum forward

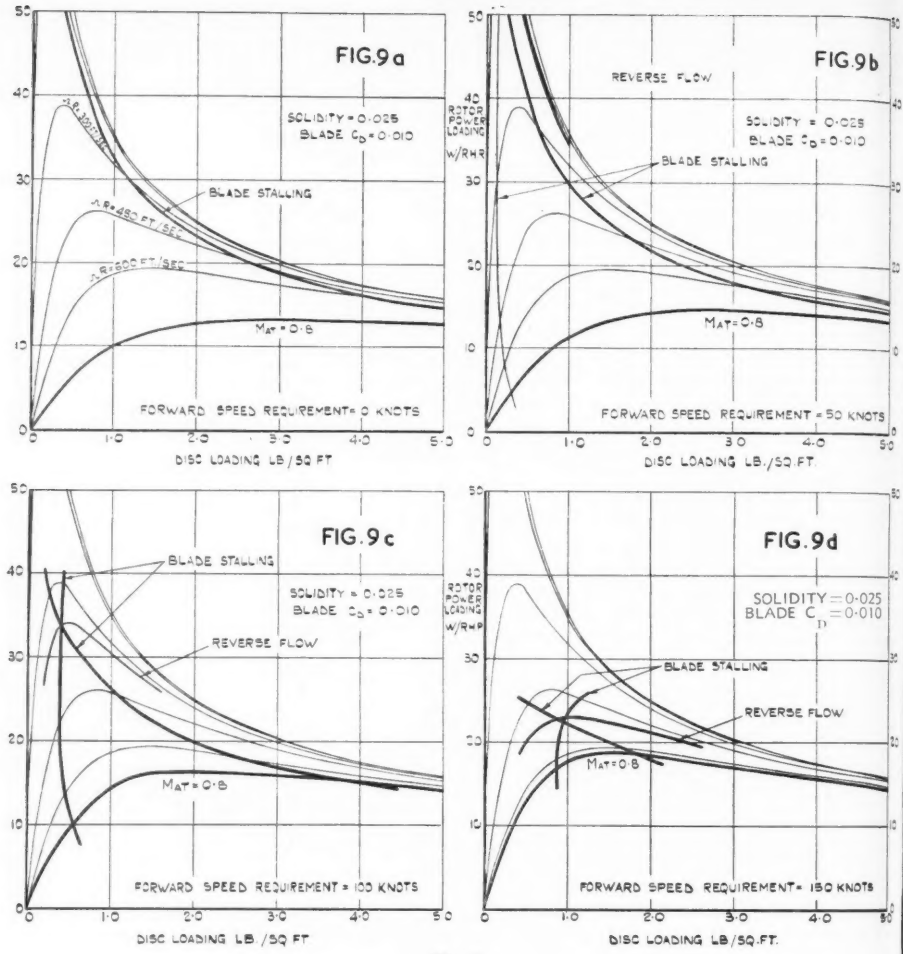


Fig. 9.
Blade stalling, compressibility, and reverse flow boundaries superimposed on Fig. 3.

speed which the helicopter will be required to attain, and the associated stalling, compressibility and reverse flow boundaries.

This is illustrated in Figs. 8 and 9, where the stalling boundaries given by Figs. 6 and 7, respectively, are superimposed on Figs. 1 and 3, together with the appropriate compressibility and reverse flow boundaries for a range of forward speed requirements.

It must be clearly understood that the power requirements indicated by the vertical scale refer solely to the hovering condition at 5,000 ft. They bear no simple relationship to the power requirements in forward flight. It is quite possible that a helicopter with sufficient power to hover at 5,000 ft. may still not have sufficient power to fly at, say, 150 knots (172 m.p.h.) if the parasite drag is high. Many current designs of helicopters, however, have already reached the stage where the top speed will be limited by blade-stalling considerations and not by power requirements.

The difficulty of designing helicopters to operate satisfactorily at speeds much in excess of 150 knots is abundantly clear from Figs. 8 and 9. All the boundaries rapidly close in as the forward speed increases, and

there will always be a limiting speed beyond which it is impossible to fly without encountering either blade stalling or compressibility phenomena.

7. SUMMATION.

The diagrams of this paper serve to illustrate the following broad principles governing helicopter performance in hovering flight: —

(1) While reduction of rotor solidity and blade drag are both beneficial to power economy, it is unlikely that present-day performance as expressed by "pounds weight lifted per horse-power supplied to the rotor" can be improved upon by more than about 30 per cent., using these means alone.

(2) While the highest values of total lifting force per R.H.P. are generated by rotors operating at low disc loadings and low tip-speeds, the effect of rotor blade weight is such that the greatest net lifting force per R.H.P. will be generated at medium values of disc loading and medium or high values of tip-speed, if the coning angle is limited to about 5°.

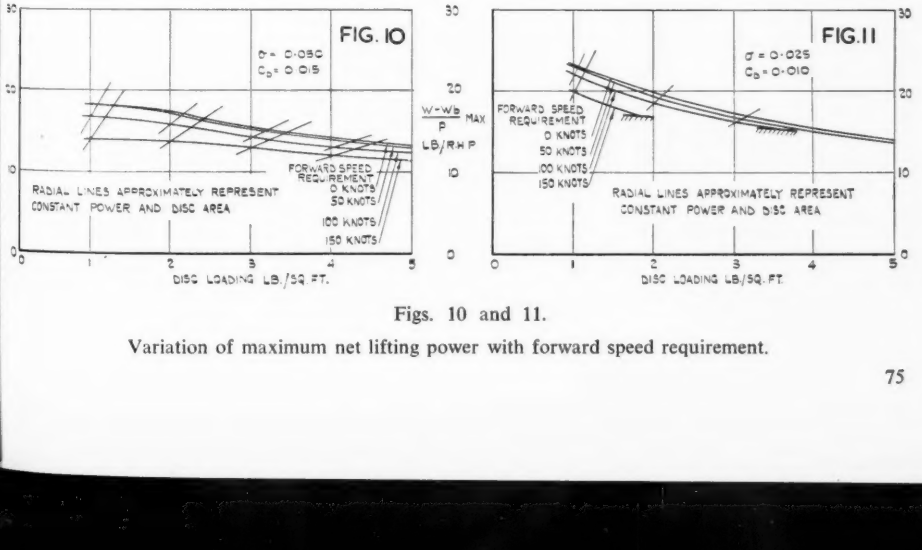
(3) If a high forward speed is required, the choice of design combinations of disc loading and tip-speed is considerably limited by considerations of blade stalling and compressibility. There are consequent limitations on the lifting efficiency obtainable in hovering flight.

(4) For similar values of disc loading and hence of rotor size, increase of hovering efficiency by decrease of solidity entails a lowering of the forward speed at which blade stalling will be encountered.

8. APPLICATION OF DIAGRAMS TO A TYPICAL PROBLEM.

As a final illustration of the conflict between the requirements of hovering efficiency and high forward speed it is interesting to consider the problem of the "flying crane," *i.e.* a helicopter designed specifically for such jobs as unloading ships or assisting in the erection of bridges and similar things. For this type of duty the helicopter need only be capable of a forward speed of, say, 50 knots (57 m.p.h.) (in order to be able to manœuvre adequately against adverse winds of at least 30 knots) (34 m.p.h.), and the aerodynamic limitations on rotor design become less severe as a consequence. It is also obvious that the percentage payload can be greatly increased in other ways under such circumstances, since very little is required in the way of equipment and furnishings, and the endurance requirement is probably less than an hour.

Cross-plotting from the stalling boundaries of Figs. 8 and 9, and correcting for blade weight by equation (4) (as in Figs. 4 and 5), gives the curves of Figs. 10 and 11. These show the variation with disc loading of $[(W - W_b)/P]$ max. in the hovering condition, for a range of forward speed requirements. The effect of over-loading a given helicopter for crane operations (keeping constant power and rotor geometry) is represented for all practical purposes by moving along a line radiating from the origin of the figure, from the original curve for, say, a 100-knot helicopter to the higher curve for a 50-knot helicopter representing a specialised crane design.



Figs. 10 and 11.

Variation of maximum net lifting power with forward speed requirement.

It is seen that only a small percentage increase in total weight is permissible but, if it is assumed that all this increase can be credited to the "payload," then the percentage increase in this quantity is quite appreciable. Fig. 12 shows the percentage increases in payload made possible by reducing the forward speed requirement to 50 knots from initial requirements of 150 knots and 100 knots, on the assumption that the original "payload" constituted 35 per cent. of the all-up weight. (Such a payload can be achieved by current helicopters when stripped for crane duties.)

Figure 12 shows that a typical helicopter with a disc loading of between 2 and 3.5 lb./sq. ft., and capable of flying at 100 knots, could lift a load some 12 to 15 per cent. heavier when restricted to a maximum speed of 50 knots. If the "crane" is compared with a similar machine designed for 150 knots forward speed, then the increased load of the crane is as much as 30 per cent. greater. These benefits are in addition to that obtaining from the lower endurance requirement.

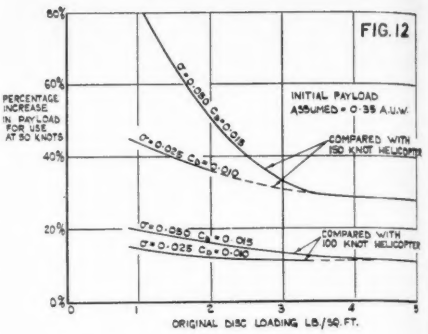


Fig. 12.

Increase in payload due to low forward speed requirement.

References

1. Glauert. On the vertical ascent of a helicopter. R. & M. 1132. November 1927.
2. Glauert. On the horizontal flight of a helicopter. R. & M. 1157. March 1928.
3. Squire. The flight of a helicopter. R. & M. 1730. November 1935.

SUMMARY OF THE SOCIETY'S ACTIVITIES

JANUARY—DECEMBER 1948

The following places on record in the Journal such parts of the Monthly Notices and other information of the Society's activities which should be permanently recorded. Activities not included in the Summary will be given in the Annual Report of the Council.

A NOTE BY THE PRESIDENT ON THE WORK OF THE SOCIETY

1. As is clearly stated in the first of the Statutes of our Society, it exists for the advancement of aeronautical science and engineering.

It is, I believe, wise to consider from time to time the significance of this primary objective; to decide what responsibilities are in fact consequent upon it; to ensure if possible that the Society is discharging these responsibilities and discharging them in ways best calculated to serve the primary purpose.

Since I became President, I have tried to review the Society's work in this way, and I have concluded that, while there are many ways of advancing aeronautical science and engineering, this aim places upon the Society two main, and in some measure interdependent, responsibilities.

One of these is the duty of establishing high standards for the profession of aeronautics. The other is, broadly, the duty of increasing technical knowledge.

I would not care to have to decide which of these two functions is the more important, and that I propose to discuss the establishment of professional standards first does not mean that I have made any such decision. I should perhaps emphasise now that the order in which various matters are introduced in this note bears no relation to any ideas of their relative importance.

2. Aeronautical science and engineering will be advanced if their practitioners are highly skilled in their professions. I hope that the truth of that observation will excuse its triteness. Further, men and women skilled in their profession, as well as their prospective employers, can fairly demand that their skill shall be recognised by the award, by a competent body, of acknowledgments of their status.

The Society seeks in consequence to ensure, by the standards of practical and academic knowledge and experience it demands through its rules and its examinations, that its technical members possess certain high minimum qualifications. These members are permitted to demonstrate their attainment of these qualifications by placing certain letters after their names.

Undoubtedly the standards demanded by the rules and examinations have been steadily raised in the past few years. The most recent changes were the result of lengthy and most careful investigation by committees which drew upon the knowledge and experience of many members. Having taken part in this work in the committees and in the Council, and having first-hand knowledge both of the conscientious way in which the Grading Committee conducts its business and of the care with which

examinations are conducted, I have reached the conclusion that the responsibility for establishing and maintaining high professional standards is one which the Society is discharging dutifully.

Technical members must feel that the technical qualifications which the Society provides are worthy qualifications to attain: the student must feel that they are worthy targets at which to aim. For them to feel so, they must be satisfied not only with the standards set by the rules, the examinations and the exempting examinations; they must feel satisfied also with the technical standing—with the prestige—of the Society itself. This prestige is in part conferred by the standards required for technical membership. In even greater measure, however, it is conferred by the manner in which the Society discharges its other major responsibility, which I briefly described as the duty of increasing technical knowledge. The Society can do this in several ways which I propose to review.

3. One of the most obvious functions of a technical society is the provision of an adequate library and library service. The Library at Hamilton Place receives nearly all the aeronautical periodicals in the world; it contains the latest aeronautical books: it includes the finest collection of old aeronautical books in the country; it has a remarkable collection of aeronautical engravings, pictures, press cuttings, photographs and handbills, recently immensely enriched by the Hodgson-Cuthbert Collection. In other words, in the Society's Library members have an unrivalled source of knowledge of the present and the past of aeronautics in works ranging from the most highly scientific to the popular: they can borrow books; they can browse in the Library itself, and it is certainly a charming room in which to browse.

Next, the Society must provide a forum for discussion. It must be the means for interchange of ideas, for technical argument. In its efforts to fulfil these functions, the Society has followed both conventional and less conventional courses. The conventional course has been the arrangement of programmes of meetings, in London and in the Branches, at which papers are read and discussed. Rather less conventional have been debates and all-day meetings at which papers associated in character have been the basis for discussions. These all-day meetings have been undoubted successes, and the policy of including one or two such meetings in each session will be continued. Another aspect of the lecture policy is to arrange for some of the lectures given first in London to be repeated at Branch meetings, and vice versa. It is also intended from time to time to hold a major lecture in a Branch centre.

The idea that the Society must be a forum for discussion must not be taken to mean that it should confine itself to promoting *public* discussion. It must facilitate private discussions and meetings of small parties or committees. This it is in a position to do. The headquarters at No. 4 Hamilton Place are not regarded, I hope, by any member as just the offices of the Society. No. 4 is a beautiful house with delightful rooms which can be used by members as the meeting place of a full-dress committee (the members of the Aeronautical Research Council and its Committees use it in this way), as the venue of a hastily arranged conference or talk between a group of people with a problem to discuss, or just as a rendezvous. I very much hope that members will always regard No. 4 Hamilton Place as *their* house, to be used for their convenience when they are in London.

However well attended lectures and discussions are, relatively only a few members can attend any particular presentation, and the chief vehicle for disseminating the knowledge which the Society purveys is undoubtedly the JOURNAL. In it the most important lectures and the discussions they provoke are printed, together with other technical material which members contribute. Through it an author reaches a very large audience, greater even than the Society's own membership suggests, for the JOURNAL has a considerable circulation in libraries and aircraft industries at home and abroad. Its standard is a matter to which the Council, with its JOURNAL Committee and its Editor, gives constant attention. It is not, however, a suitable medium for *all* the information which the Society seeks to

disseminate, and this leads me to the discussion of other methods of giving technical information which are recent in the Society's history.

In the early days of the War, Mr. B. S. Shenstone, a Fellow of the Society, drew the Council's attention to the great difficulties attendant upon applying in design the knowledge gained, and being gained, of sheet metal construction. As a result, an attempt was made to overcome the difficulty. A committee was set up to gather, sift and issue information on stressed skin structures. To the cost of this work the Society of British Aircraft Constructors and the Ministry of Aircraft Production made contributions, and the information was issued in the form of Data Sheets. These Data Sheets were, until recently, necessarily treated as secret papers, but the ban has now been lifted and they will be generally available shortly, when reprinting has been completed. Although the original distribution was limited by the secrecy condition, these Data Sheets achieved a circulation which marked them as an undoubted success, a success which impelled the Council to extend the service to Data Sheets on aerodynamics. An appropriate Committee organised this venture and these sheets also proved of great value to technicians. It is hoped that now that we are on the point of issuing them without security restrictions their usefulness will be appreciated over a much wider field.

The appreciation which the Society received for its ventures in disseminating information in this way led them to consider what further duties they could perform of a similar nature. The result was the setting up of a Technical Committee under the Council, and that Committee has had the help not only of the Structures and Aerodynamics Sub-Committees, whose work I have just referred to, but of more recently formed sub-committees with the duties of investigating the issue of digested information on performance, fuels, materials and instruments. Not all these Committees have found it feasible to work in the same way. The Fuels Sub-Committee has been formed in collaboration with the Institute of Petroleum and the result will be a few Data Sheets covering a limited field, issued by the Society with the Institute's help. The Materials Committee has found that the medium of Data Sheets is unsuitable in its work. Instead, it is sponsoring the issue, under the Society's imprint, of certain monographs on aircraft materials. These monographs will be published as books, and judging by the quality of the first manuscripts and the professional standard of the authors, like the Data Sheets they will be of great value to the aeronautical profession.

The most recent proposal of the Technical Committee, which the Council have agreed to, is the twice-yearly issue of a second periodical containing technical and scientific material of a more specialised kind than is normally published in the JOURNAL. It is hoped that this second periodical will pay its way and will provide members not only with a publication of a type noticeably lacking in this country, but a means of publishing some of their more highly technical papers which would not have the wide appeal demanded by the large circulation of the JOURNAL.

All this work is, for our Society, of the nature of pioneer work. Through it, the Society is performing a considerable service and, in the judgment of the Council, it is work which will bring the Society credit. Although in the end, if our calculations are correct, the result will be satisfactory financially, in these early days it is necessary to spend money. The Society could not itself finance the work without cutting into its Endowment Fund—its capital—which the Council believe should be kept intact for its original purpose, the provision of its future home, for as long as possible. Consequently, the Council acknowledges gratefully its appreciation of the financial help it has received in furthering these technical activities, both from the Ministry of Supply and the Society of British Aircraft Constructors, whose equal contributions, originally applied only to the work of the Structures Sub-Committee, have been handsomely increased to assist in the work of the other sub-committees.

In pursuit of its aim of increasing technical knowledge, the Society must provide opportunities for its members to make contacts on, so to speak, a broad front. Gatherings at lectures inevitably tend to be gatherings of people with an interest in common, frequently a specialised interest. It is not easy to arrange for large numbers

of members with widely varying aeronautical interests to foregather. The Society makes one attempt annually to do this—at its Garden Party. At this party there is the dual attraction of the latest aircraft and accessories, and the probability of meeting a large circle of friends and acquaintances. Undoubtedly this function has been a great success, a success due in no small measure to the generosity and assistance of the Society of British Aircraft Constructors, whose annual exhibition, after serving its function as a trade display, has been transformed for the past two years into the Society's Garden Party.

The Council wishes that more such opportunities for large-scale gathering together of its members and friends were possible. The most it can do in addition however, is to stage smaller social gatherings from time to time at its headquarters and in its Branches, and this policy, which appears to be justified by its steady popularity—witness the attendances at the 80th Anniversary functions and at the recent receptions to see the Hodgson-Cuthbert Collection—will be continued by the Council and, I hope, by the Branch Committees.

The Branches of the Royal Aeronautical Society are somewhat unusual in constitution. Many members of the Society are members of Branches, but many members of Branches are not members of the Society. A Branch starts around a few members of the Society living in a particular area, and grows up by the adherence of not only other local members of the Society, but of local people who are not members of the Society. These people are Branch members and for a very small subscription enter into the affairs of the Branch.

I believe the Branches have "Branch" responsibilities as well as "Society" responsibilities. Or perhaps it is more accurate to suggest that the Branches may be expected to have their own interpretations of the Society's responsibilities. For example, the advancement of aeronautical science and engineering should include, in a Branch, the advancement of the aeronautical knowledge of those who have been keen enough to become Branch members and, ultimately, the cultivation of these interested individuals until they become full members of the Society. In other words the Branches are at the same time recruiting centres and links between the professional parent body and the layman. The Branches have a great work to do—and they do it well—in forming sound opinion on aviation matters in their areas. They have a large measure of autonomy, and they do not all work in the same way, but they all work to the same end—the advancement of aeronautical science and engineering.

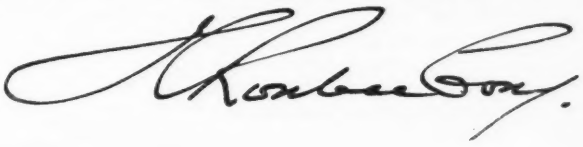
So far, by implication, I have been restricting myself to increasing knowledge and interchanging ideas within the United Kingdom. In addition, if it is to keep abreast of thought overseas, the Society must encourage liaison with the British Commonwealth and Empire and with foreign countries. The Society has Branches in Australasia, Canada, South Africa and New Zealand, and the Council is considering how the association of their work with ours, admirably strengthened by the institution in 1945 of the British Commonwealth and Empire Lecture, can be more closely integrated.

Relations with the Institute of the Aeronautical Sciences in the U.S.A. have been close ever since that Institute was founded in 1932. In recent years Americans have alternated with British as Wilbur Wright lecturers in London and Wright Brothers lecturers in the U.S.A. The high peak of this very pleasant and fruitful association was reached in 1947 when, at the suggestion of our Society, an Anglo-American Conference was sponsored in London jointly by the Institute and the Society. For this new venture, the Society had very practical support from the Society of British Aircraft Constructors and the Conference was truly a tremendous success.

The other foreign organisation with which the Society has begun to develop a cordial liaison is the Association Française des Ingénieurs et Techniciens de l'Aéronautique, which was founded as recently as 1944, and which is doing excellent work in France. Already members of the Society have lectured in France, and recently one of the Association's eminent council members, M. Lucien, lectured here.

4. My review of the Society's duties and the way it is performing them, adumbrated in the foregoing paragraphs, leads me to conclude that we are working generally along the right lines. For my part, I shall always be grateful to members with views on improving the Society's work if they will put forward their ideas. There is, no doubt, much more for us to do if we are to remain a virile and useful force in aeronautics. But so long as we keep the primary aim—the advancement of aeronautical science and engineering—clearly in view, so long as we pursue a balanced policy and continue to attract the adherence of all kinds of aeronautical engineers and scientists, so long as our members take seriously the election of their representatives on the Council we shall, I think, not go far wrong in our affairs.

In what I have written above I have confined myself to the Society's duties. I have not tried to deal with the members' duties, because I think that in these matters our members need little guidance. In his Message on the occasion of our 80th Anniversary, the immediate Past-President wrote: "It is a well-established engineering maxim that you cannot get more work out of a machine than you put into it." A very similar metaphor was used by the Chairman of the Automobile Division of the Institution of Mechanical Engineers in an address which, because of its well expressed views, the Editor of the JOURNAL included in our Society's Notices for December last. The point need not be pressed further, although I would express my appreciation, shared by the Council, to the many, many members who clearly recognise the implications of the metaphor—the people who work hard for no material reward on Council Committees and on Branch Committees, who steadily support the lectures, who take part in the discussions, who write papers, who, prevented by their locations from more active participation, keep in touch by correspondence, and all those who show in a hundred different ways their appreciation of the Society's existence. Their reward is their achievement of a Society growing in numbers, strength and influence in times which can scarcely be deemed propitious.



March 1948.

ANNUAL GENERAL MEETING

The Annual General Meeting of the Society was held on Friday, 7th May 1948, at 4 Hamilton Place, London, W.1, at 6.0 p.m.

PRESENT:

Sir John S. Buchanan (Vice-President) in the Chair.

J. Bell (Associate)
G. F. Briginshaw (Associate Fellow)
S. Camm (Fellow)
A. J. Clark (Associate Fellow)
T. S. D. Collins (Associate Fellow)
W. N. Cumming (Associate Fellow)
M. J. B. Davy (Fellow)
Lt.-Col. H. Delacombe (Associate)
Dr. G. P. Douglas (Fellow)
C. Robson Elgie (Associate)
A. H. C. Greenwood (Associate)
N. J. Hancock (Associate)
Norman Hill (Associate)
J. Housego (Graduate)
G. Ingram (Associate)
E. T. Jones (Fellow)
Dr. D. M. A. Leggett (Asociate Fellow)
Prof. R. L. Lickley (Fellow)
H. E. Lightly (Associate)
E. W. Lofts (Associate Fellow)
A. R. May (Associate Fellow)
Cmdr. F. Warren Merriam (Fellow)
M. B. Morgan (Fellow)
Major Gen. H. J. Parham (Companion)
E. Pribram (Associate Fellow)
N. E. Rowe (Fellow)
S. Scott Hall (Fellow)
J. J. Sullivan (Associate)
W. Tye (Fellow)
Capt. C. F. Uwins (Fellow)
Capt. A. S. Wilcockson (Associate Fellow)

In attendance: The Secretary, Assistant Secretary and Miss Barwood.

The Chairman informed the meeting that the President, Dr. Roxbee Cox, was unable to preside that day owing to his absence in Sweden.

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1. The Secretary read the Notice convening the Meeting.

2. The Report of the Council on the state of the Society and the Balance Sheets of Aerial Science Limited and Aeronautical Trusts Limited for the year ended 31st December 1947 were presented.

   The adoption of the Report was proposed by Major G. P. Bulman and seconded by Dr. G. P. Douglas, and carried.

3. As a result of the Ballot the Secretary reported the following nominations to fill the vacancies on the Council:

   E. J. N. Archbold
   Lord Brabazon of Tara
   A. V. Cleaver
   Dr. G. P. Douglas
   A. G. Elliott
   J. W. F. Housego
   W. Tye

4. The Secretary read the names of those proposed for Fellowship and passed by the Council as follows:

   Fellowship Elections 1948

   John D. Akerman (from Associate Fellow)
   Ronald Eric Bishop (from Associate)
   Herbert George Brackley (from Associate Fellow)
   Jan M. Burgers
   Wilhelm Challier (from Associate Fellow)
   Charles Chapleo (from Associate Fellow)
   Newsome Henry Clough (from Associate Fellow)
   Handel Davies (from Associate Fellow)
   Henry Davies (from Associate Fellow)
   Guy Charles Du Merle (from Associate Fellow)
   Guy Garrod
   Sydney Barrington Gates (from Associate Fellow)
   John Joseph Green (from Associate Fellow)
   William Rede Hawthorne (from Associate Fellow)
   Nicholas John Hoff (from Associate Fellow)
   David Keith-Lucas (from Associate Fellow)
   Rene Lucien (from Associate Fellow)
   Gustavus McAlpine (from Associate Fellow)
   Donald Campbell MacPhail (from Associate Fellow)
   Clark Blanchard Millikan
   Eric Stanley Moult (from Associate Fellow)
   Gordon Neil Patterson (from Associate Fellow)
   Ronald Smelt (from Associate Fellow)
   Ernest William Still (from Associate Fellow)
   Charles Cecil Turner (from Associate Fellow)
   Cecil Gordon Vokes (from Associate Fellow)
   Trevor Cresswell Lawrence Westbrook (from Associate Fellow)
   Howard Arthur Wills (from Associate Fellow)

5. Mr. C. R. Elgie (Associate) proposed that Messrs. Price Waterhouse be re-appointed Auditors for the ensuing year for Aerial Science Limited and Aeronautical Trusts Limited. Dr. G. P. Douglas seconded the proposal which was passed unanimously.

Mr. P. G. Masefield (Fellow) proposed a vote of thanks to the Staff of the Society for the work done during the year, particularly for the extra work involved in the Anglo-American Aeronautical Conference.

Mr. Scott Hall (Fellow) seconded the proposal, which was carried unanimously.

Mr. N. J. Hancock (Associate) expressed disappointment at the postponement of the All Day Discussion on Safety in Aircraft and the Chairman, Sir John Buchanan, assured him the subject was very much in the minds of the Council who hoped to fix a new date for the discussion.

The Meeting ended at 6.25 p.m.

HONOURS

The following members of the Society received awards in 1948:

NEW YEAR'S HONOURS—JANUARY 1948

KNIGHTS BATCHELOR

H. R. Ricardo, F.R.S. (Fellow)
R. V. Southwell, F.R.S. (Fellow)

K.B.E.

Sir Frank Spriggs (Honorary Fellow)

G.B.E. (Military Division)

Air Chief Marshal Sir Guy Garrod (Associate)

C.B.E.

Major F. B. Halford (Fellow)
Mr. F. A. King (Associate Fellow)
Major A. A. Ross (Fellow)

O.B.E.

Mr. R. N. Dorey (Fellow)
Mr. J. P. Jeffcock (Fellow)
Capt. A. G. Store (Associate Fellow)

A.F.C. (Royal Navy)

Lt. Commander S. G. Orr, D.S.C. (Associate)

BIRTHDAY HONOURS

KNIGHT BATCHELOR

A. Gouge, B.Sc., M.I.Mech.E., F.I.Ae.S. (Fellow)

ORDER OF THE BATH (Military Division)

Knight Commander

Air Marshal the Hon. Sir Ralph A. Cochrane, K.B.E., C.B., A.F.C. (Associate Fellow)

ORDER OF THE BATH (Civil Division)

Companions

H. M. Garner, M.A. (Fellow)
O. Thornycroft, O.B.E., B.A., M.I.Mech.E. (Fellow)

ORDER OF THE BRITISH EMPIRE (Military Division)

Knight Commander

Acting Air Commodore F. Whittle, C.B., C.B.E., M.A., D.Sc., F.R.S. (Fellow)

O.B.E.

Wing Commander A. J. Nicholas (Associate Fellow)

ORDER OF THE BRITISH EMPIRE (Civil Division)

C.B.E.

G. R. Dawbarn, M.A., F.R.I.B.A. (Fellow)

O.B.E.

C. H. Griffiths, A.R.C.Sc. (Fellow)
W. Tye, B.Sc. (Fellow)

M.B.E.

W. H. Darlington, M.Sc., A.M.I.Mech.E. (Associate Fellow)

HONOURS

Air Commodore F. R. Banks, C.B., O.B.E., F.R.Ae.S., who gave the first Louis Bleriot lecture to the Association Française des Ingenieurs et Techniciens de l'Aéronautique on 12th May 1948, was appointed a Commander of the Legion d'Honneur by the French Government for services rendered to France in connection with the development of aero-engines of all types. The presentation was made by the French Minister for Air at the banquet given by A.F.I.T.A. following the first Louis Bleriot lecture.

ANGLO-AMERICAN AERONAUTICAL CONFERENCE 1949

Arrangements were begun in September 1948 for the Aeronautical Conference to be held in 1949.

The Society has been in close consultation with the Institute of the Aeronautical Sciences and a number of lectures have already been arranged. The Conference will spread over five days and will be followed by a number of visits to aircraft firms and to Langley Field and elsewhere.

Mr. A. D. Emil, representing the Institute of the Aeronautical Sciences, paid a visit to England during the year, and at a dinner given to him by the Council he explained what steps the Institute were taking to make the Conference an outstanding event in the year 1949 in the history of the Institute. Mr. Emil handed to the Council, on behalf of the Council of the Institute, the following resolution:—

"WHEREAS, it is deemed highly desirable to augment the cordial relations that now exist between the Institute of the Aeronautical Sciences and the Royal Aeronautical Society of Great Britain, and

WHEREAS, the advancement of the aeronautical sciences in the respective countries can best be served by a periodic inter-change of views on various technical matters by representatives of the two Societies,

BE IT THEREFORE RESOLVED, that the President of the Institute of the Aeronautical Sciences, on behalf of the Council of the Institute, extend to the President and Council of the Royal Aeronautical Society an invitation to designate representatives to meet with the Institute of the Aeronautical Sciences in New York City between 22nd May and 6th June or any other dates that may be mutually agreed upon, to discuss problems of common interest in the field of the aeronautical sciences."

The following reply from the Council was sent to the Institute:—

"The President and Council of the Royal Aeronautical Society welcome the invitation of the President of the Institute of the Aeronautical Sciences to designate representatives to meet with the Institute of the Aeronautical Sciences in New York City between 22nd May and 6th June 1949 to discuss problems of common interest in the field of the aeronautical sciences.

The President and Council are convinced that by such an inter-change of views on technical matters by representatives of the two Societies, the cordial relations which now exist between the Institute of the Aeronautical Sciences and the Royal Aeronautical Society will be enhanced and their objects, namely, the increase in knowledge of aeronautical science and engineering, will be furthered. They have therefore great pleasure in accepting the invitation of the Institute."

ELECTION OF PRESIDENT AND VICE-PRESIDENTS

At a Special General Meeting held on 7th August 1947 the following resolution was passed unanimously:—

That the President and Vice-Presidents elected in May or June 1947 under the rules then operative, to take office on 1st October 1947 and to serve for one year, shall continue in office until the May meeting of the Council in 1949 notwithstanding anything to the contrary contained in Rules 20 and 23 of the Society.

Dr. H. Roxbee Cox, B.Sc., D.I.C., F.I.Ae.S., F.R.Ae.S., was elected President of the Society to serve from 1st October 1947 to May 1949, under the above resolution.

The following were elected Vice-Presidents of the Society to serve for the period 1st October 1947 to May 1949, under the above resolution.

Sir John Buchanan, C.B.E., A.M.I.Mech.E., F.R.Ae.S.
W. G. A. Perring, Esq., F.R.Ae.S.
N. E. Rowe, Esq., C.B.E., B.Sc., D.I.C., F.R.Ae.S.

ELECTIONS OF NEW MEMBERS

JANUARY 1948

Associate Fellows

Douglas Edward Ackland (from Graduate), Phillip Brittain Aitken, James William Adderley, John Harry Clapham Atkins, Thomas Bancroft, Kenelm Joseph Godfrey Bartlett, Eric Victor Betts, Joseph Black (from Graduate), George Boyce, Stanley Charles Joseph Caliendi (from Graduate), Nevil John Eugene Chaplin (from Graduate), Mircea Michael Conea (from Graduate), Anthoney Michael Creedon (from Graduate), Ivan H. Driggs, John Dubbury (from Graduate) Reginald John Ford, Kee Poon Gan, George Denzil Gawthrope, John Hadji-Argyris, Arthur Barry Haines, Joseph Fletcher Harriman (from Associate), George Henry Hiscock, Lionel Russell Jenkins (from Graduate), John Menzies Kay (from Graduate), Fred Kirk, Tung-Hua Lin, Murray Parker McHeffey, Subramania Ramamritham, Fred Lees Robinson, Charles William Rossiter-Smith, Vernon Gerald Walker, John Charles Ward (from Associate), Norman Ralph Kenneth Wheatley, Norman Arthur White, Charles Horace Lionel Wynne.

Associates

John Sandford Balkwill, Leonard Logoz Bridgman, Frank Bright (from Student), Alan Harold Buchanan (from Companion), Frederick John Cable, Harry Cheers, William Bathie Cowan, William Herbert Douglas, Geoffrey Crosbie Jobling, Subhandhu N. Majmudar, Alexander Maurice Raffael.

Graduates

Norman Frederick George Banfield, Hazel Marjorie Bigg, Jeffrey Laurence Crowder, Harry Frank Downton, Andrew James Duxbury (from Student), Ralph Gordon Evans, Sydney Kelsey, Ian Robert Lyon (from Student), William James Johnstone MacDonald, Alastair McKay (from Student), Pran Nath Malhotra, Alfred Charles Martin (from Student), Charles Albert Millidine, Basil Robert Edwin Riddaway, Robert James Ross (from Student), David Michael Scott, Walter Robert Stirling (from Student), John Keith Yates (from Student).

Students

Derek Watson Ashworth, Frederick Edward Baker, Anthony John Barker, Peter John Bell, Philip Gordon Binns, Charles Russell Chrisp, Peter Hartley Coutts, Peter James Cross, John Perran Curry, William Ernest Digweed, Patrick Cornelious Alfred

Donovan, Alan Sidney Henney, Maurice Donald Hodges, John Day Holland, George Charles Brian Harvey Kenrick, Eric David Marchant, Charles Frederick Matthews, John Osborn, Brian Henry Randall, Peter William Shaw, Guy Shepherdson, Thomas Smith, Alan Sydney Thurley, Albert William George Utting, Gerald Alfred White.

Companion

Jacqueline Borgel.

FEBRUARY 1948

Associate Fellows

Thomas Edward Garth Bowden (from Graduate), Venkatachalam Cadambe, Richard William Spencer Cheetham, Elmer Coton (from Associate), Kenneth Douglas Drysdale, Charles Fletcher, Arthur Charles Frye (from Student), John Gardiner, Norman Grosvenor Garner (from Associate), Ernest Lawrence Harris (from Associate), Norman Alexander John Harry (from Graduate), Maurice Hermiston, Douglas Gilbert Hitchcock (from Graduate), Subramania Ramamritham, George Ingram Robinson, David John Saunders (from Graduate), John Henry Shelley.

Associates

John Edgar Boyden, William James Hall, Geoffrey Dimmock Nicoll, Francis Eustace Edmund Truscott, George Albert Willis.

Graduates

Stanley Butler (from Student), John Cecil Gibbings (from Student), Geoffrey Bransom Griffiths (from Student), George Ian Livingston Gunn (from Student), Derek George Harris, John Anthony Hay (from Student), Alfred Hucknall (from Student), Robert Frank Harry Kriebel, Milton Lalas, Joseph Stanley Linton, William Maurice Locke (from Student), Jack Harry London (from Student), Peter Ronald McFarlane (from Student), Gilbert McIntosh, John Brian Maw, Peter Edward Thomas Oakley (from Student), Donald William Bernard Owers, Colin Charles Parsons (from Student), Anthoney Mervin Peduzzi (from Student), Colin Walter Rhodes (from Student), Robert Welch (from Student), Michael George Wilde (from Student).

Students

Alan Frederick Constantine, Bruce Kerrill De Rouffignac, Kenneth Thomas Fulton, David Francis Hoare, Christopher Huggins, Murray Alleyn Lowry, Harry Hartley Malley, Richard Dennis William Miller, John Evan Mitchell, Philip Owen, Derek Herrington Peckham, Anthony Lester Pendleton, Sven Thomas Röed, Peter Travers Ross, John Tudor, Ronald Charles Wakeford, Edward Wood.

MARCH 1948

Associate Fellows

John Lindsay Allen, Arthur Charles Boswell (from Graduate), David Cardwell (from Graduate), Geoffrey James Barnard Hall (from Graduate), John Glyn Jones (from Associate), Meyer Julian Kemper (from Associate), Herbert Joe Knevitt, Victor Henry Knight, John Brown Lambie, James Arnold Latham, Kenneth John Leighton (from Graduate), Norman Spencer Makins (from Graduate), Alfred Charles Marshall, Edwin John Ewart Newman (from Graduate), Francis Joseph Newton (from Graduate), Robert Deans Peggs, Arthur Ernest Polden, Norman Purssell (from Graduate), Hywel Rolands Rees, Gilbert Charles Riall (from Associate), Anthony Arthur Rose (from Graduate), Charles Francis Norman Seaman, Eric William Troman, Keith Winterbotham Turner, Harry Tyler (from Graduate), Vivian Humphrey Wickham (from Graduate), John Malcolm Nicolson Willis (from Student), Arthur Jack Willshire (from Graduate), Frederick James Woodcock.

Associates

Donald Charles Allen, Peter Endsleigh Castle, Cyril Arthur Catherall, Frederick James Alfred Collins, Patrick Arthur Dean, Cecil Austin Denne, Eric George Franklin, Bernard Godfrey George Gilmore, Charles Ronald Griffiths, Arthur John Hinkley, Gordon Edward Hughes, Michael John Debenham Inskip, Eric Isherwood (from Student), George Frederick Jackson, Jacques Alecxis Kirk (from Student), Charles Henry Lang, Edwin Campbell Lawson, James William Lockley, Sidney John MacNamara, Charles Albert Martin, John Desmond Murphy, William Paul Nicol, Haydene Rece Porter, John Griffin Portlock, Robert Bisset Wight Scott (from Companion), Ronald Frederick Oliver Smith, Laurence Higgon Stopforth, David George Thorpe, Charles Horace Wells, George White.

Graduates

David Richard Blundell (from Student), Brian Arthur Howard Botting, Leslie Harvey Bridge, Stanley Milton Butler, John Edward Clough (from Student), Henry Cook, Thomas Martin Corson, William Harold Dainty, Kenneth Leslie Day (from Student), Norman Frederick Harpur (from Student), Richard Alan Harriss (from Student), Henry Brian Iles, Francis George Irving (from Student), Marcus Llewellyn Bruss Jones, Robert John Jupe, Gavin Stuart Kermack (from Student), Rene Herbert Le Claire, Eric Jesse McKenna (from Student), Denys John Mead (from Student), Stanley Bernard Newport, Donald Glyn Oliver, Forbes George de Brie Perry, Alan Vincent Rushton, Frank Smith, Roy Starmer (from Student), John Francis Tring (from Student), Anthony Roy Turley (from Student), Ronald Frederick West (from Student), William Francis Wiles.

Students

James Joseph Ansell, William James Avis, Ronald Frank Bailey, John Francis Barlow, David Alan Hughes Bird, Gerald Evan Gladwin Bishop, Brian Edward Boyce, Michael Frederick Burle, Ian Bernard Butterworth, Bernard Caiger, Dennis James Carey, Edward Christopher Carter, Arthur George Creak, Eric Ernest Denyer, John Stewart Drabble, John Derek Ellis, David Harold Frean, Kenneth Herbert Griffin, William Hodgson Haigh, John Dennis Hallett, James Michael Howe, John Clubb MacDonald, Eugene Peter McLoughlin, Ivor Armfield Payne, Lionel Chatham Pitt, Robert James Revill, Robert John Rockcliff, William Colin Ruler, Kenneth Robert John Shearwood, Peter Duncan Stewart, Jonathan Swainson, Robert Graham Taylor.

Companions

Leonard Atherton, Gordon Fryer (from Student), Curt B. A. Schiff, John Anthony Scott.

APRIL 1948

Associate Fellows

Eric Cutts Beard, George Stephenson Bowey, Alastair Hugh Cameron, R. Chambert-Loir, Ernest Charles Clear Hill (from Graduate), John Carol Collins (from Graduate), Roger Savernake Dickson, Ronald Dimerline (from Graduate), Jiri Dolezal (from Associate), Clement George Wilson Ebbutt (ex-Student), Maxwell John Edmonds (from Graduate), Arthur Evans, Ivor Everson (from Student), George William Futcher, Thomas Frederick Richard George, William Kenneth Grant (from Associate), William Henry Gregory, Reginald Edward Wynyard Harland, Rex Anthony Harvey (from Graduate), Raymond Holl (from Graduate), Krishnagiri Thooppil Gopalakrishna Iyengar, David Mellor Jameson (from Graduate), James Morrison Johnston, John Kinsella, Arthur Turner Lancaster, Denys Marius Louw, Harold Lyne, Douglas MacKenzie, Owen Finlay MacLaren, Peter Fyfe Mouritz (from Graduate), Robert James Newton (from Graduate), Elton John Perks (from Graduate), Frank Pilkington (from Graduate), William Beesley Roy Pocock, R. Ravaud, John Philipp Milford Reid (from Graduate), Frederick

Charles Sanders, Joseph Handford Stevens, Stuart Summersbee (from Graduate), Arthur Tannenbaum, Alfred Everett Thornton, Arthur Trevor Williams, William Trefor Williams.

Associates

Reginald Percy Bailey, Frederick John Ballard, Archibald Horace Cholerton, Thomas David, Myles Lonsdale Formby, John Reginald Gardiner (from Student), Ronald John Frederick Geary, Sydney John Goates, Ronald Edward Green, Leslie Leetall Harland, Alexander Saunders Johnston, Donald John Maxwell Keys, John Lawley Lendrem, Donald Lowry, Hubert Charles Beverley Mackey, Claude Percival May, Horatio Brian Hartley Parkhurst, William Hubert Perry, Thomas Picken, Harold Pound, William A. Rendell, Edward Charles Saggs, William Scott, Alexander Whitelaw Sinclair, John Daniel Snook (from Student), William Denis Learoyd Theed, Herbert Henry Watkinson, Wilfred George Wotton, Eric Paul Zander.

Graduates

Michael Thomas Caiger (from Student), Richard Henry Collins (from Student), Alan Charles Conolly, Thomas Frederick Curragh, Albert Denton Curry, Alan Donkin (from Student), Roy Farmer, Francis Leslie Freeman, Vernon Frederick Gardener (from Student), John Grieve (from Student), Stephen John Hancock, Edwin Jones, Mostyn David Kimber, Henry Anthony Knight (from Student), Dennis Lewis, Om Parkash Mediratta, Peter Meiklem (from Student), Catherine Gertrude Newton, Hedley James Organ, Raymond James Potter (from Student), Peter Robinson (from Student), Christopher Sutcliffe, John Thompson, John Bruce Thompson, Frank John Weight, Maurice Oliver Wilmer, Sydney Francis Wilson.

Students

Maurice Charles Baxter, Douglas Francis Beanland, Stephen Joseph Wyndham Brown, Donald Edward Brian de Casmaker, Ronald Cole, Eric Henry Crudden, Herbert David Denchfield, Henry Clare Eatock, Roland Anthony Gray, Aubrey Dillon Hill, Edward Louis Houghton, Norman Jackson, Simon Kugler, Anthony Charles Edward Leach, Alexander Vivian Leake, Victor Taylor Legge, John Dennis Micklem, Brian Ronald Morris, Thomas William Neil, Godfrey Edward Noble, Rosslyn Phillips, John Pringle, Richard George Proudlove, Geoffrey Reece Scott, Sidney Charles Swatton.

Companions

John Stuart Rowland Muller-Rowland, Ronald Selby Walker.

MAY 1948

Associate Fellows

Archibald Morton Ballantyne, Augustus Alfred Ward Barron, William Edward Breacker (from Graduate), Reginald Bruce Godfree, Zygmunt Stanislaw Ipohorski-Lenkiewicz (from Associate), Reginald Watson Kenworthy, John Reginald Lupton (from Graduate), Coorg Scrinivasachar Rangaswamy, Walter Percival Cuthbert Soper (from Graduate), Clifford Arthur Bowman Wilcock.

Associates

Peter Crossland, Thomas Ellison Dunwoody, Arthur Henry Nelson Emden (from Companion), Horace Joseph Alexander Galaud, Richard John Ifield, Arthur Kingsnorth (from Student), John Leworthy, Henry Lightly, Gordon McLachlan, Alfred John Macey, Herbert Kitchener Newton, Arthur Henry Porter, Ezz El Din Ramzi, Robert James Ritchie, John Ernest Dudley Scott, John Joseph Sullivan, Reginald Tillyard.

Graduates

Royston Herbert Blyth, Frederick Alfred Cousins, Edwin Jones, James Roland Miller (from Student), Raymond Matthew Ryan, Priykant Avantilal Vasavada.

Students

John Ian Golesworthy, Merlin Kilick, Thomas Ambrose O'Sullivan, Stephen William Tonkin, Geoffrey Walter Webber.

JUNE 1948

Fellows

Ronald Eric Bishop (from Associate), Herbert George Brackley (from Associate Fellow), Johannes Martinus Burgers (from Associate Fellow), Wilhelm Challier (from Associate Fellow), Charles Chapleo (from Associate Fellow), Newsome Henry Clough (from Associate Fellow), Henry Davies (from Associate Fellow), Guy Garrod (from Associate), Sidney Barrington Gates (from Associate Fellow), John Joseph Green (from Associate Fellow), William Rede Hawthorne (from Associate Fellow), David Keith-Lucas (from Associate Fellow), Gustavus McAlpine (from Associate Fellow), Donald Campbell MacPhail (from Associate Fellow), Eric Stanley Moult (from Associate Fellow), Gordon Neil Patterson (from Associate Fellow), Ronald Smelt (from Associate Fellow), Ernest William Still (from Associate Fellow), Charles Cyril Turner (from Associate Fellow), Cecil Gordon Vokes (from Associate Fellow), Trevor Cresswell Lawrence Westbrook (from Associate Fellow).

Associate Fellows

Joseph Thomas Adey, William John Allen, Peter Frederick Ashwood (from Graduate), Reginald Bance (ex-Associate), Ronald Oliver Bater (from Graduate), Kenneth Bentley (from Student), William Bignold, Sanderson Buchanan (from Graduate), John Carter, Leslie James Chantler, Ralph Alexander Cochrane, Peter Draper (from Associate), Richard Streatfeild Easby, William Ronald Farr (from Graduate), Ronald George Franklin (from Graduate), George William Gallia (from Student), Ivor Dennis Harnden Gibbins (from Graduate), Norman Bryan Goodsell (from Graduate), Edward James Gough (from Graduate), Ernest John Hancock (from Graduate), Arthur Hillier (from Companion), Frederick Leighton Hodgess, John Charles Douglas Howland, Alan Baird Hunter (from Graduate), Denis Keogh Kempston (from Associate), Warner Tjardus Koiter, Denis Moore Langford (from Associate), Verdon Osbert Levick, Richard Arthur McGill, William Bernard Mathison (from Graduate), Robert John Millson (from Associate), Roland Matthew Morton (from Graduate), Arthur Frederick William Ollett (from Associate), Richard William Robert Osmotherly (from Graduate), Thomas Stuart Parramore (from Graduate), Geoffrey Peacock, Robert Henry Peacock (from Associate), Harry Pearson, James Pritchett (from Associate), Kenneth David Raithby, John Procter Rayner (from Graduate), Douglas Norman Scard (from Associate), Frank Herbert Scrimshaw, John Alfred Henry Shepperd, Walter Frederick Shilling (from Graduate), Leslie Carl Skinner, Vernon Leonard Smith, Arthur Frederick Toe (from Graduate), Arthur William James Upton (from Graduate), Charles Francis Frederick Walsh, Frederick Douglas Ward (from Graduate), Hugh Gordon Wenham, Ronald Edward James White, William Harry Yoxall.

Associates

Stanley Bateman, Wilhelm Beets, Clarence George Wilfred Betts, John Gemmell Bogle, Raymond Norman Bournon, Jan Joseph Bukovsky (from Companion), Victor Noel Butler, Donald Angus Allan Cameron, Gerard James Chandler, Vernon Wilfred Clarkson (from Student), Fletcher Sydney George Codling, Robert Harold Doggett, Edouard Raoul Durbec, Laurence Sydney Edwards (from Student), Clifford Charles Flynn, Clifford Fox, Joseph Gibson Green, John Fraser Hall, Reginald Alexander Herbert, Geoffrey Leonard Howitt, Percy William Lambell, Desmond Bernard Law, David Colin Rocliffe Lee, John Clutha McPhee, Edward William Merriman, Frank Alfred Bernard Newton, Hubert Leslie Peddle, William Solomon Reed, John Spencer Rivaz, Albert Edwin Robinson, Kenneth Charles Rogers, Henry Alan Roxburgh, John Hazel Seabrooke, Alfred Kenneth Sherwood, Richard Vincent Smith, Frederick William Stockhausen, Ralph

Thomas Sutton, Charles Herbert C. Swaine, Samuel George Taylor, Percy Samuel Victor Vallis, Geoffrey Theodore Van-Weegen, Edward Wilson Whitley (from Student), Walter Blackett Wilson, Roland Albert Woodworth.

Graduates

John Alexander Anderson (from Student), John Charles Francis Brunswick, James Douglas Buchanan, Michael Trevor Corben, David Jeremy Fermo (from Student), Georgina Joan Griffith, James Ivor James (from Student), Elizabeth Barbara Puttick, John Lewis Reddaway, Octavio Gasper de Souza Ricardo, John Raymond Robinson, John Marler Sloper (from Student), Geoffrey Thomas Tollett, Frederick George Arthur Williams, Ralph Darkin Williams (from Student), Derek John Wood (from Student), David John Wright.

Students

Malcolm Derek Chamberlain, Eric Percival Maurice Dorrington, George Edward Gadd, Norman Keith Ayliffe Gardner, Donald Edward Hartley, Desmond James, Anthony Francis Keech, David John Baron Lethbridge, John William Paulsen, John Everard Rayner, Robert Brian Salmon, Dennis Charles Saxton, Malcolm Edmund Scott, David Thomas John Stops, Patrick Francis Cranleigh Swash, Robert Irvine Taylor, Dennis Meredith Walsh, Harry Nigel Newson Wemyss, Robert Owen Willis.

Companions

David Trevor Evans (from Student), Peter Frederick McKinney, Douglas Johnston Reoch, Richard Henry Reynolds, Herbert Charles Smith, Simon George Warrender.

JULY 1948

Fellows

John D. Akerman (from Associate Fellow), Handel Davies (from Associate Fellow), Guy Charles Du Merle (from Associate Fellow), Nicholas John Hoff (from Associate Fellow), Rene Lucien (from Associate Fellow), Clark Blanchard Millikan, Howard Arthur Wills (from Associate Fellow).

Associate Fellows

Ju-Yung Cheng, Frederick Clay (from Graduate), Neilson John Hancock (from Associate), Alun Raymond Howell, James Howard Johnston, James Arneil Lang, Jesse Millington Marshall, Alfred John Nicklin, Percival Edwin Quintin Shunker, Norman Fred Simmonds (from Graduate), Albert William Thomas, Geoffrey Swan Cabot Vautier (from Graduate), Robert Hendry Weir, David Williams, Rene Maurice Michel Wisner.

Associates

Richard Allen, John Stanley Booth, Clifford Claude Caple, Alan Trevor Ching, John Henry Richard Chubb, Donald Louis James Corner (from Student), Ronald Fortescue Cronin, Kenneth James Boyd Dunlop, Ernest Clement Ely, Rupert Forrester-Simms, Alan William Nisbett Garratt (from Student), Leslie Greville Hamlet, Eric Thomas Hanley, Albert Norman Hossbach, Joseph Richard Kilner, Reginald Kenneth Law, Peter Martin (from Student), Herbert Alfred Oldfield, Kenneth Arthur John Pettet (from Student), Edward Howard Ruddock, David P. Samson, Idris Reginald George Smith, Rex Frederick Stedman, Alexander Stuart Watson, Frank Wilkinson.

Graduates

Brian Bodley Collins (from Student), Roy Edward Lambeth (from Student), John Freeman Leach (from Student), Barrie Desmond Morris (from Student), John Henry Risdon (from Student), Thomas James Taylor, William Idris Thomas (from Student), Sydney Allandale Urry.

Students

Philip Bruce Atkins, Brian Stevens Campion, Anthony David Cowell, Peter George Edgington, Douglas Archie Hickman, Peter Sinclair Howieson, Arthur Albert Keeler, Peter Robin Lomas, Eric Mosedale, Khusro Kemalur Rahim, Roger Gordon Richards, Geoffrey Thomas Scales, Richard Gerard Sharpe, Robert Charles Wallin, Alan Robert White, Donald Robert Willey, James Maitland Woods.

AUGUST 1948

Associate Fellows

James Douglas Anderson (from Graduate), Ralph Leonard Apsden, Harold William Russell Banting (from Associate), William Gall Driver, Giuseppe Gabrielli, James William Spracking, Roland Graham L'Estrange Wallace (from Graduate), James Benjamin Yates (from Associate).

Associates

Sunder Lal Atal, Keith Berkley Crosby, Nils Jacob Gille, William Wightman McCombe.

Graduates

John Frederick Clarke (from Student), Reginald George Evans (from Student), Geoffrey Lindley Harrison, James Dougal Harris (from Student), William Risbee Heald, William George Hearle, Antoni Lewandowski, Reginald Arthur Langley, Robert Rose, Frank Melvin Stansfield (from Student), Brian Worsley Bolton Shaw, Prabandam Srinivasan, Alan John Wangford, Peter William Wreford.

Students

Khwaja Mohiuddin Ahmed, Reginald Albert Lloyd Arkell, Ian Campbell Carrott, Alan Arthur Hawkins, Charles David Hollis, Bryan Rex Noton, Robert Charles Pennicott, Raymond Victor Sabin, John Derek Teare.

Companions

William Tait Gill, Sydney Lacy Hebard, Alfredo Ramon Junque-Gasso, Ernest George Cuthbert Leathem, Peter Sweetman, Peter George Tranter.

SEPTEMBER 1948

Associate Fellows

Lewis Roland Barrett, John Albert Beard (from Graduate), Reuven Benzwi (from Graduate), John Laurence Bright (from Associate), Fred Paul Bruce, William Henry Burdon, Henry Busen-Schmitz (from Associate), Thomas Dorian Robertson Carroll (from Associate), Harold Thomas Chapman, David Mostyn Davies (from Graduate), David John Day, Wilfred Hubert Dukes, Eric Oliver Dummer (from Graduate), Reginald William Dunn, Ronald George Fall, Alan Edgar Foster (from Graduate), Jack Arthur Froude (from Graduate), Zygmunt Funt, Ivor Edward Giles (from Student), Eric Martin Goodger (from Associate), Raymond Walter Frank Gould, Cyril Grantham, Ronald Albert Charles Hallett, John Douglas Hamilton (from Graduate), Lily Kathleen Harrison, Geoffrey Bryan Hewitt, Sidney Greville Higgins, David Siegfried Holmes (from Associate), Thomas Arthur House, Harry Brynmor Hughes, Owen Lewis Hyde (from Student), James Jackson, Thomas Edmund Johnson (from Associate), John McPherson, Sydney Herbert Masters, Henry William Newman, George William Nunn (from Associate), Donald Pierce (from Graduate), George Frederick Pitts (from Student), Manfred Pohoryles, Leslie Alex Guy Reeve, Antony Horrex Richardson, Richard Charles George Thomas Rogers (from Associate), Herbert Derrick Ruben (from Graduate), Arthur Clarence Sanderson (from Graduate), James Anthony Hosking Sargeaunt, Alan Sharpe, S. Gopalakrishna Shivshankar, Albert William Edward Stanley (from Associate), Donald Bull Swinbanks (from Graduate), Eugeniusz Szomanski, Maung Kyaw Tha, Henry Charles Baden Thomas, Donald Watson Tripp (from Associate), Hugh Wason Turner (from Graduate), Peter Hayward Wall (from Graduate), Bernard John Watson (from Associate), Edward Weiser, George Albert Willis (from Associate), Cecil Solomon Wills, Robert Norman Wimshurst, Joseph Woodward (from Associate).

Associates

Allan Noel Norman Abbott, Henry William Adams, Hugh Adams, George Aubrey Allen, John Edward Atkins (ex-Associate), Roland Shirley Austin, William George Ayres, John Edward Baker, Alan Beaton, Arthur Douglas Bentley, James Robert Booth, Harold Edwin Braithwaite, Lewis Charles Budd, Leonard George Burnard, Ivor Jenkins Cadwallader, John Frederick Carrington Carrington, Hector Catlow, Gerald Arthur Champniss, George William Chirgwin, Leonard Edwin Swaffield Cowan, Geoffrey Hugh Docker, Horace William George Donkin, Geoffrey Dorman, Ernest George Faulkner, Edmund James Galpin, Charles Joseph Thomas Gardner, Adam Rutherford Gourlay, Clifford Graham-Jones, Charles Cyril Graves, Edward Gregory, Cecil Charles Head, Philip Charles Heming, Leonard Francis Hubbard, Herbert Charles Humphreys, Leslie Donald Kent, Trevor Fleetwood Lawrence, James William McCombie, John McDonald, Harold Stanley Martin, Derek Mason, Edward Harry Maule, Jocelyn George Power Millard, Thomas Victor Nelson, Desmond Henry Clements Nixon, Maxwell Norman Oxford, Frank Reginald Parker, Brian Stanley Pittaway (from Student), Tom Ernest Pratt, Henry Shawbrook, James Patrick Spillane, Donald Lee Taylor, Leslie William Norman Walker, Reginald George Warne, Eric Michael Welch, Joseph Thomas White, David John Williams, John Augustine Wren.

Graduates

John Russell Baxter (from Student), Guy Bransby Charter (from Student), John Waterston Furness, Peter Michael Gray (from Student), Richard Francis Harrison, Michael Alaric Josselyn Morton Hayward, Ralph Spenser Hooper (from Student), John Dudley Lewis, John Reighcraft Purchase (from Student), Edward Albert Ridge (from Student), Dennis John Tyler.

Students

William Allan Chapman, Ronald Arthur Cole, John Noel Critchley, Alexander William Houston, Gordon Eric Monger, John Gordon Hedley Pearce, Hamid Sapru Riaz, James Velkou, James Henry Wilson.

Companion

Biren Roy.

OCTOBER 1948

Associate Fellows

Trevor Ronald Ashcroft (from Graduate), Edward George Bowen, Peter Wright Brooks (from Companion), John Bryce (from Graduate), William Devon Doble (from Graduate), Louis Maurice Gardiner (from Graduate), Thomas Anthony Gawade, Garth Owen Jones, George Victor Richard Jones (from Associate), Stefan Josef Krukowski, John Francis Lewis, Robert B. Meyersburg, Erik Blyth Nelson (from Associate), Laurence Henry Gordon Sterne, Maurice Albert Taunton (from Graduate), Vivian Victor Wilson Vallance, Percival John Waite, Paul Howard Wilkinson, William Manton Willey.

Associates

Henry Rossbottom Bairsto, Ronald Edward Bird (from Student), Eric Hider Bowers, Arthur Charles Bridge, Charles Carson Brodie, Mudumbai Narasimha Chari, William Kenneth Crow, Selwyn Howard Evans, Kenneth Walter Booth Fouweather, John Eric Heald, Norman Frederick Hildyard, Adi Murzban Irani, Albert Frederick Jones, James Caldwell Hole Kortright, Raymond Lawrance, Peter Godfrey Lawrence, Reginald William Clifford Mills, Walter Ian Scott-Hill, Eric Roy Sisson, Briercliffe Bleackley Smylie, Alec George Sollis, Alfred George Leslie Standley, Freeman Jesse Steel, John William White, Stuart Edward White.

Graduates

John Michael Bennett (from Student), Robert James Martin Beverly, Franck John Maurice Bonnères (from Student), Benjamin Joseph Prior, John Charles Rendle, Robert Alexander Vair.

Students

Richard Douglas Archer, Denys Ingraham McCullough, Eileen Muriel Neill, Ronald Eugene O'Donnell, William Alan Pollard, George Lancaster Ronson, Robert Francis Henry Woodberry, George Reginald Wrixon.

Companion

Robert Nelson.

NOVEMBER 1948

Associate Fellows

Frank Bernard Baker, Herbert Charles Barton, Joseph William Birkle, Arthur Joseph Kenneth Carline, Edgar Theodore Carpenter, Walter Leonard Clarke, Ernest Charles Covell (from Associate), Horace Richard Davenport, William Henry Dresser, Neville John Ebsworth (from Associate), Reginald Joseph Fenner, Sydney Harrison-Smith, Frederic Charles Haus, William Heaton, Herbert William Heslop, George Kenyon, Leslie Robert Knight (from Graduate), Ronald Stephen Loveland, Dennis John Lyons, James Fraser Montgomerie, Constantine Morley, Jethro Jack Canham Oakley, Leslie Thomas Palmer (from Associate), Donald Westwood Richardson (from Associate), William Sutcliffe, John Bernard Joseph Thorpe.

Associates

James Robert Anderson, Arthur George Herbert Angell, Charles Lewis Baker, Peter Bennison (from Student), Victor Francis Bingham, Frederic Lister Chadwick, Walter Patrick Copinger, Kenneth Costall, Roland Arthur Victor Dismore, Bertram James Elkins Arnold Field, John Frederick Gardner, John Kenneth Hadwin, Bernard John Hammett, Hawkesley Murray Arthur Hayes, Robert Leslie Hughes, Basil Barry Jupp, Robert King, Norman Frederick Lamb, Sidney William George Marchant, Edgar William Lovejoy, Leslie Milnes, Douglas Robert Morgan, Harold Lewis Newman, Frederick Thomas Pankhurst, Albert Henry Ridley, Raymond Frederick Sargent (from Student), Edward Elijah Weekley, Gilbert Frank Wilkinson, Harold Wilson.

Graduates

Denis William Bryer, Ronald Frederick Cash, Norman Stanley Currey, Pierre Robert Genot, Kenneth Herbert Griffin (from Student), Harold Frederick Hawkins, Thomas McCloghry, Stanislaw S. Schaetzel (from Student), George Tolmie Skinner (from Student), Arthur Montgomerie Thompson (from Student), Richard Phillip Wade.

Students

John Cabread Hall, Peter Milns, Charles Roy Pratt-Barlow, Robert Charles Leslie Sample, George Thompson, John Thompson.

Companions

Jamsked Minocher Cowasjee (from Student), William Thomas Fogarty, Kenneth Stuart-Smith.

DECEMBER 1948

Associate Fellows

Frank Andrews, Robert Angles (from Graduate), Alfred William Ballinger, Arthur Lionel Benns (from Graduate), Richard Peter Boswell (from Student), Douglas Thornton Brown (from Graduate), Sidney Riley Brown, Francis Frederick Chamberlain, John Charles Digby Cotes (from Graduate), Kenneth William Course (from Associate), David George Creamer, Brinley Daniel Davies, Frank Frodin (from Graduate), Alfred Louis Fussell, Michael Alec Garnett (from Graduate), Arnold Roydon Bennett Gay, Harry Fenner Glover, Neville Thomas William Harper, Richard George Harvey (from Graduate), Douglas William Holder (from Graduate),

Brian Joseph Howison (from Graduate), Robert Guy Huggett (from Graduate), Jules Louis Albert Jarry, Ronald Francis Jelly, Adrian Albert Lombard, Neville Lloyd Lupton (from Associate), David Leonard Marples, William Charles Mongar (from Graduate), Stanley Thomas Moore (from Associate), Stanley Patrick Osborne, Alfred Charles William Rattle (from Graduate), John Howard Rea, Kopula Rama Reddy, Kenneth Edgar William Ridler, Eric William Robson, Hermann Schoenen (from Associate), Roger Hugh Spikes (from Graduate), Edward Egan Storm, Derrick Laird Taylor, Trevor Harry Thornton (from Graduate), John Walmsley, John Henry Walmsley (from Associate), Basil Laycock Walsh, Norman Stanley Watson.

Associates

John Greenwood Alderson, Frank Cutts-Watson (from Student), Ronald Mackinnon Denny, Thomas George Goode, Peter Hadfield, Paul Albert Hartman, Arthur Bertram Roy Hudson, Norman George Huett, Harry McPherson Johnston (from Student), Hubert Samarasinghe Kaviratne, Kenneth Riley Firth Kenworthy, Robert Kenyon, Archibald Norman Kingwill, Ernest Sidney Larkin, John Alfred William Long, Thomas Beattie McClure, Leslie Martin, Douglas Stirling Maxwell, Wilfred Thomas Morgan (ex-Associate), Dudley Cyril Morris, Robert Cox Munro, John Charles Occo, Douglas Seymour Parnacott, John Charles Parry-Jones, Theodore Stanley Revell, John Alfred Ross, Boris Peter Slusarev, Geoffrey Ward Stallibrass, Edwin Arthur Stevenson, Douglas Reginald Pemberton Tipler, Charles Leonard Trevithick, Edward Henry Victor Windsor, Michael Sewell Wooding.

Graduates

Gordon Leyland Anderton (from Student), Frederick Edward Baker (from Student), Edward George Underwood Band (from Student), Anthony John Blaxill (from Student), Raymond Montrose Brown (from Student), Andrew Liddell Buchan (from Student), Harry Charles Channon, Harry Derrick, Graham Norman Galton, Hugh Graham Gillespie (from Student), Thomas Cyril Greaves (from Student), Robert David Mauleverer Harper, Norman Herbert (from Student), Gordon Stephen Frederick Holman (from Student), Peter Bertram Hoskin, Donald Howard (from Student), Philip Jarvis Johnson (from Student), John Arthur Charles Kentwell, Denis Lawrence Lofts (from Student), Donald Lewis Matthews (from Student), Derek Paul Morriss (from Student), Michael John Neale, Keith Jones Oldham (from Student), John Osborn (from Student), Ralph James Pitt, Charles Peter Seward Popkin (from Student), Robert John Rockliff (from Student), John Denman Sibley (from Student), Ronald Montague Silverblatt (from Student), Brian Spencer Soan (from Student), James Walsey Tootell, Ronald Thomas Turner (from Student), Ronald Charles Wakeford (from Student).

Students

Josef Aretz, Derek Bollworthy, Alan Edward Brock, Bryan Robert Alexander Burns, Derek Eaves, Douglas Bryon Garland, William John Harbottle, Janet Patricia Harris, Robert John Hayter, Lancelot John Hope, John Whalley Jellicoe, Frederick Claude Kinchela, Eckart Lemberg, Stuart Gordon Lennox, Laurence Arthur Piper, James Stanford Plowman, Brian Edward Rayner, Stuart Raymond Sarrailhe, Harold George Sevier, Peter John Sheath, David Harry Smith, Victor Frederic Thompson.

Companions

Ali Zubeyir Demirguc, Eugenio Horacio Zucal.

REVISED SYLLABUS FOR ASSOCIATE FELLOWSHIP EXAMINATION

The Revised Syllabus was approved during the year and will come into operation in two stages.

Part I of the examination became operative on 1st January 1949.

Parts II and III of the examination become operative on 1st January 1950.

The last examination under the present syllabus will be held during December 1949, and until then candidates can take the examination under either syllabus.

Candidates who have not completed the examination under the present syllabus at that time will not be allowed to continue the examination under these conditions but will be granted exemption under the new conditions in the subjects of Part I which have been passed.

A revised list of exempting examinations comes into operation with the new syllabus on 1st January 1950.

The present syllabus is now *out of print*, but copies of the syllabus for *individual* subjects will be supplied to candidates on request.

ASSOCIATE FELLOWSHIP EXAMINATIONS

The following were the successful candidates in the Associate Fellowship Examination held in December 1947:—

HOME

W. J. Allen, Strength of Aeronautical Materials and Structures, Theory of Machines; J. Ansell, Pure Mathematics; R. J. Barnard, Applied Mathematics; H. G. Bell, Pure Mathematics; V. M. G. Bennett, Pure Mathematics; R. A. Berridge, Pure Mathematics, Strength of Aeronautical Materials and Structures, Design (Aircraft); G. W. Bleasdale, Theory of Machines; A. A. Blythe, Pure Mathematics, Strength of Aeronautical Materials and Structures; E. L. Bond, Applied Mathematics; F. R. J. Britten, Pure Mathematics, Strength of Aeronautical Materials and Structures; D. W. Bryer, Applied Mathematics, Theory of Machines; J. Bunting, Applied Mathematics; T. D. R. Carroll, Design (Aircraft); R. Cash, Applied Mathematics, Theory of Machines; R. S. Challender, Theory of Internal Combustion Engines; L. J. Chantler, Design (Aircraft); J. B. Chaplin, Theory of Machines; G. B. Charter, Applied Mathematics, Theory of Internal Combustion Engines; J. K. Chaudhuri, Applied Mathematics; P. Child, Pure Mathematics; J. F. Clarke, Design (Aero Engines); A. L. Cole, Pure Mathematics; K. W. Course, Design (Aero Engines); E. N. Crabbe, Pure Mathematics; K. D. Crisp, Applied Mathematics; R. D. Dale, Design (Aero Engines); J. L. Davis (Miss), Aerodynamics; H. D. Denchfield, Applied Mathematics; A. A. Down (Sgt.), Theory of Internal Combustion Engines; G. G. Drummond, Applied Mathematics; J. R. Duncan (Miss), Strength of Aeronautical Materials and Structures; B. Eales, Applied Mathematics, Theory of Machines (tie 1st place), Design (Aero Engines); W. L. Farish, Theory of Internal Combustion Engines, Design (Aero Engines); D. J. Fermo, Applied Mathematics, Theory of Machines, Design (Aero Engines); J. A. Fuller, Applied Mathematics, Theory of Machines; J. R. D. Fuller, Applied Mathematics, Theory of Machines; O. D. Furlong, Design (Aircraft); E. Gearceoura, Applied Mathematics, Theory of Machines; J. Gilchrist, Strength of Aeronautical Materials and Structures; F. Glew, Design (Aircraft); P. M. Gray, Applied Mathematics, Theory of Machines, Design (Aero Engines); P. C. Grigg, Aircraft Materials; D. Gwynne (Miss), Strength of Aeronautical Materials and Structures; A. L. Hall, Pure Mathematics; B. A. Harding, Pure Mathematics; B. J. Hastings, Pure Mathematics; W. G. Hearle, Theory of Internal Combustion Engines (1st place); W. R. Hoskin, Design (Aero Engines); R. R. Howlett, Applied Mathematics, Theory of Machines, Design (Aero Engines); D. I. Hunt, Applied Mathematics; J. Hurry, Pure Mathematics; A. E. Jefferson, Pure Mathematics, Theory of Internal Combustion Engines, Aircraft Materials (1st place); R. F. Jelly, Design (Aircraft); A. S. Johnston, Aircraft Instruments (1st place); R. E. Lambert, Pure Mathematics, Design (Aircraft); C. D. Langley, Applied Mathematics; K. Lavanchy, Applied Mathematics; M. P. Le Lohe, Design (Aircraft); T. McCloghry, Applied Mathematics, Theory of Machines; J. McPherson, Applied Mathematics (tie 1st place), Theory of Internal Combustion Engines, Design (Aero Engines); G. Maidanik, Applied Mathematics, Theory of Internal Combustion Engines, Theory of Machines; J. G. Male, Pure Mathematics; J. M. Marshall, Design (Aero Engines); S. H. Masters, Applied Mathematics, Strength of Materials; J. C. Martin, Pure Mathematics; A. Measures, Design (Aircraft) (1st place); R. Melling, Applied Mathematics, Theory of Machines, Design (Aero

Engines) (1st place); H. C. H. Merewether, Applied Mathematics (tie 1st place), Theory of Machines, Design (Aero Engines); H. H. Morgan, Applied Mathematics, Theory of Machines; D. A. O'Clarey, Applied Mathematics, Theory of Machines, Design (Aero Engines); F. A. A. Palmer, Pure Mathematics; T. Papis (F/O.), Pure Mathematics, Theory of Internal Combustion Engines, Theory of Machines; T. Pasternak, Applied Mathematics, Theory of Machines; L. C. Pitt, Aircraft Materials; J. M. Ramsden, Pure Mathematics; G. Reed, Applied Mathematics, Theory of Internal Combustion Engines; Theory of Machines; J. H. Risdon, Design (Aero Engines); J. G. Russell, Applied Mathematics, Aerodynamics (1st place); G. P. Sandeman (Miss), Pure Mathematics; D. Scard, Design (Aircraft); H. Busen-Schmitz, Design (Aero Engines); D. M. S. Simpson, Pure Mathematics; C. E. Tharratt, Theory of Machines; A. M. Thompson, Pure Mathematics, Theory of Machines; P. J. W. Tuffs, Aerodynamics, Theory of Machines (tie 1st place), Design (Aircraft); S. A. Urry, Pure Mathematics (1st place), Strength of Aeronautical Materials and Structures, Aerodynamics; D. W. R. Vincent, Design (Aircraft); G. D. Walley, Pure Mathematics; H. L. Wallis, Applied Mathematics, Theory of Machines; P. D. Walters, Strength of Aeronautical Materials and Structures; K. R. Warren, Applied Mathematics; J. A. Webb, Navigation and its Application to Aeronautics; G. A. Willis, Applied Mathematics, Theory of Machines, Wireless Telegraphy and Telephony and their Applications to Aeronautics (1st place); D. F. Wilson, Pure Mathematics; C. C. Wood, Aircraft Materials; N. Woodwell, Applied Mathematics; A. J. Wright, Pure Mathematics; W. B. Wright, Pure Mathematics; M. A. Yusuf, Pure Mathematics.

ABROAD

M. S. Balasubramanian (Madras), Theory of Internal Combustion Engines; J. G. Borman (Pretoria), Aircraft Materials; A. Cooke (Montreal), Air Transport; F. J. Dorsey (Calgary), Strength of Aeronautical Materials and Structures; F. J. Edwards (F/Sgt.) (B.A.F.O.), Applied Mathematics; A. H. S. Fernando (Bombay), Design (Aircraft); Md. Sultan Husain (Aligarh), Pure Mathematics; F. D. Jooste (Pretoria), Theory of Internal Combustion Engines; H. S. Liner (Bulawayo, S. Rhodesia), Applied Mathematics (1st place tie), Aircraft Design (1st place), Aerodynamics (1st place); H. A. R. Rao (Bangalore), Applied Mathematics; S. Krishnaswami Rao (Bangalore), Strength of Aeronautical Materials and Structures (1st place); G. D. Sadhwani (Bombay), Pure Mathematics; L. S. W. Smyth (Melbourne), Aircraft Materials; L. Townend (W/O.) (Singapore), Navigation and its Application to Aeronautics (1st place); T. V. Trinder (Pretoria), Aircraft Materials.

The following candidates were successful in the Associate Fellowship Examinations held in June 1948:—

HOME

F. B. Adler, Applied Mathematics; J. Aretz, Pure Mathematics; N. Barford, Pure Mathematics, Design (Aircraft); R. J. Barnard, Theory of Machines; H. C. Barton, Applied Mathematics, Strength of Aeronautical Materials and Structures, Design (Aircraft); G. T. Biermann, Applied Mathematics; J. W. Birkie, Pure Mathematics; Theory of Machines, Aircraft Instruments—Theory and Design; D. W. Bryer, Theory of Internal Combustion Engines; J. Bunting, Theory of Machines; W. H. Bunting, Applied Mathematics; R. F. Cash, Theory of Internal Combustion Engines; R. S. Challender, Pure Mathematics; J. B. Chaplin, Pure Mathematics, Aerodynamics; G. B. Charter, Air Transport; J. Cocheme, Meteorology and its Application to Aeronautics; A. F. Constantine, Pure Mathematics, Strength of Aeronautical Materials and Structures; T. N. Corkill, Design (Aircraft); K. W. Course, Pure Mathematics, Theory of Internal Combustion Engines; N. S. Currey, Aerodynamics; J. L. Davis (Miss), Design (Aircraft); E. D. Dixon, Aircraft Materials; F. A. Drayton, Applied Mathematics; J. R. Duncan (Miss), Aerodynamics; P. R. Dymond, Strength of Aeronautical Materials and Structures; D. Eccles, Pure Mathematics, Theory of Machines; P. A. Edwards, Design (Aircraft); W. L. Farish,

Applied Mathematics; J. R. D. Fuller, Theory of Internal Combustion Engines; J. F. Ferguson, Applied Mathematics; O. D. Furlong, Applied Mathematics; A. L. Fussell, Pure Mathematics, Theory of Machines, Wireless Telegraphy and Telephony and their Application to Aeronautics (1st place); P. L. E. Gallimore, Strength of Aeronautical Materials and Structures, Design (Aircraft); N. Ghose, Applied Mathematics; G. K. F. Green, Pure Mathematics; A. R. Hammond, Applied Mathematics, Theory of Machines; C. P. Hands, Aircraft Materials; P. J. Harradine, Pure Mathematics, Strength of Aeronautical Materials and Structures, Aerodynamics; J. P. Harris (Miss), Pure Mathematics; L. H. W. Harris, Air Transport; D. W. Hayward, Pure Mathematics; W. Heaton, Applied Mathematics (tie 1st place), Theory of Internal Combustion Engines, Design (Aero Engines); H. T. Howard, Aerodynamics; D. I. Hunt, Strength of Materials, Design (Aircraft); K. Jackson, Applied Mathematics; R. F. Jelly, Applied Mathematics, Theory of Machines; F. A. Johnson, Pure Mathematics; J. B. E. Keebie, Aerodynamics; J. A. B. Lambert, Pure Mathematics; C. D. Langley, Strength of Aeronautical Materials and Structures; M. P. Le Lohe, Strength of Aeronautical Materials and Structures; T. McCloghry, Theory of Internal Combustion Engines, Design (Aero Engines) (1st place); P. McLaughlin, Applied Mathematics; W. Macpherson, Applied Mathematics; K. K. Mitra, Applied Mathematics; H. H. Morgan, Theory of Internal Combustion Engines; C. Morley, Pure Mathematics, Strength of Materials, Design (Aircraft); G. K. C. Pardoe, Pure Mathematics (1st place), Strength of Aeronautical Materials and Structures, Aerodynamics; J. C. Pathak, Applied Mathematics; H. L. Peddie, Strength of Aeronautical Materials and Structures; F. C. Petts, Applied Mathematics; C. P. S. Popkin, Applied Mathematics (tie 1st place), Theory of Internal Combustion Engines; A. Powell, Pure Mathematics, Strength of Aeronautical Materials and Structures (1st place), Aerodynamics (1st place); J. Reid, Applied Mathematics; J. Rosenthal, Applied Mathematics; E. W. Saben, Design (Aircraft); G. P. Sandeman (Miss), Design (Aircraft); S. S. Schaetzel, Pure Mathematics, Strength of Aeronautical Materials and Structures, Aerodynamics; D. M. S. Simpson, Strength of Aeronautical Materials and Structures; H. P. Singh, Pure Mathematics; S. H. P. Smith, Theory of Machines (1st place), Applied Mathematics; G. N. Srivastava, Pure Mathematics; J. Terajewicz, Pure Mathematics, Strength of Materials, Aerodynamics; C. E. Tharratt, Applied Mathematics; A. M. Thompson, Strength of Aeronautical Materials and Structures, Design (Aircraft); J. B. J. Thorpe, Pure Mathematics, Theory of Machines, Aircraft Instruments—Theory and Design (1st place); B. O. Thurston, Pure Mathematics; R. Toone, Pure Mathematics, Strength of Aeronautical Materials and Structures, Aerodynamics; J. Tudor, Applied Mathematics; P. E. Tweed, Applied Mathematics, Design (Aircraft); A. Uydens, Pure Mathematics; D. W. R. Vincent, Applied Mathematics, Theory of Machines; R. P. Wade, Applied Mathematics, Strength of Aeronautical Materials and Structures; J. Bell-Walker, Applied Mathematics, Theory of Machines; C. H. Walker, Applied Mathematics; J. Walmsley, Theory of Internal Combustion Engines, Aircraft Materials (1st place); J. H. Walmsley, Theory of Machines; P. D. Walters, Aerodynamics; J. Watkins, Applied Mathematics; N. S. Watson, Pure Mathematics, Strength of Aeronautical Materials and Structures, Theory of Machines; D. F. Wilson, Air Transport (1st place).

Abroad

C. G. Andrews (Wellington, New Zealand), Applied Mathematics; V. R. Bunyard, (Port Elizabeth, South Africa), Applied Mathematics; C. Crowley (Calgary, Canada), Aircraft Materials; G. Dietiker (Calgary, Canada), Pure Mathematics, Aircraft Materials; R. F. Lamothe (Calgary, Canada), Aircraft Materials; H. J. McNeill (Calgary, Canada), Pure Mathematics, Strength of Aeronautical Materials and Structures, Aircraft Materials; F. H. McKnight (Calgary, Canada), Pure Mathematics, Strength of Aeronautical Materials and Structures; J. N. Mathur (Bombay, India), Aircraft Materials; S. K. Rao (Bangalore, India), Design (Aircraft) (1st place); M. R. Roper (Wellington, New Zealand), Applied Mathematics; C. C. Sumbler (Calgary, Canada), Pure Mathematics, Strength of Aeronautical Materials and

Structures, Aircraft Materials; C. R. Taylor (Cpl.) (B.A.F.O.), Aerodynamics, Meteorology and its Application to Aeronautics; L. M. Treleman (Calgary, Canada), Pure Mathematics, Aircraft Materials (1st place); B. Willard (Cpl.) (R.A.F. Changi), Applied Mathematics.

SECTION A

The following were the successful candidates in Section A of the Associate Fellowship Examination held in June 1948:—

W. M. Lewis, Elementary Mathematics, English; D. M. Sanderson, English; R. G. Thompson, Elementary Mathematics, English.

MEMBERS' SUBSCRIPTIONS

At the Special General Meeting held on 23rd October 1947, a Postal Ballot was called for, under the Rules, to consider the proposals for an increase in the subscriptions. Out of 4,295 voting members of the Society (Founder Members, Fellows, Associate Fellows and Associates) 1,979 voted as follows: For the proposed increase in annual subscriptions 1,386; against the proposed increases 593.

The new rates of subscription which came into effect on 1st January 1948 are as follows:—

	HOME	ABROAD
	£ s. d.	£ s. d.
Fellows	5 5 0	4 4 0
Associate Fellows	4 4 0	3 3 0
Associates	*3 3 0	*3 3 0
Graduates (aged 21-25)	2 2 0	2 2 0
Graduates (aged 26-28)	2 12 6	2 12 6
Students (aged under 21)	1 1 0	1 1 0
Students (aged 21 and over)	1 11 6	1 11 6
Companions	3 3 0	3 3 0
Founder Members	2 2 0	2 2 0

The amounts of Entrance and Transfer Fees are unchanged.

* Any Associate elected before 1st October 1947 may, if he wishes, elect not to receive the Journal, and in this case his subscription will be reduced by £1 1s. 0d.

WILBUR WRIGHT MEMORIAL LECTURE

The 36th Wilbur Wright Memorial Lecture was delivered on Thursday, 27th May 1948, by A. Gouge, B.Sc., F.R.Ae.S., on, Size in Transport: A review of the development of the subject, with particular respect to size and the application of its lessons to Air Transport. The complete report appeared in the July 1948 Journal, page 407.

LOUIS BLERIOT LECTURE

The first Louis Bleriot Lecture, which has been instituted by the Association Française des Ingènieurs et Techniciens de l'Aéronautique, was given in Paris on the 12th May 1948. The lecture, " The Art of the Aviation Engine," by Air Commodore F. R. Banks, C.B., O.B.E., M.I.Aut.E., F.I.P., M.S.A.E., M.I.Mech.E., F.R.Ae.S., was read in French on behalf of Air Commodore Banks by Colonel Guy du Merle, C.R.D.

The Bleriot lecture will be given alternately in Paris and London under the auspices of the Association Française des Ingènieurs et Techniciens de l'Aéronautique and the Royal Aeronautical Society respectively.

LECTURES—1948

15th January—Joint lecture with the Institute of Fuel. Gas Turbine Accessory Systems, by O. N. Lawrence, M.A., A.M.I.Mech.E., A.F.R.Ae.S.

29th January—The Flight Testing of Helicopters, by W. Stewart, B.Sc.

12th February—The Aerodynamics of the Gas Turbine, by A. R. Howell.

26th February—The Evolution of the Design of an Aeroplane, by Professor R. L. Lickley, B.Sc., D.I.C., F.R.Ae.S.

18th March—Flight Testing at High Subsonic Speeds, by H. Davies, B.A., M.Sc., A.F.R.Ae.S.

15th April—Visual Aids for Low Visibility Conditions, by E. S. Calvert, B.Sc., A.R.C.Sc.I.

27th May—The 36th Wilbur Wright Memorial Lecture, by A. Gouge, B.Sc., F.R.Ae.S.

30th September—Fourth British Commonwealth and Empire Lecture. Some Economic Factors in Civil Aviation, with Emphasis on Civil Aircraft and their Prospective Trends of Development, by Peter G. Masefield, M.A., F.R.Ae.S., M.I.Ae.S., G.Inst.Mech.E.

6th October—Some Aspects of Power Plant Development, by Dr. E. W. Still, B.Sc., A.C.G.I., A.F.R.Ae.S., A.M.I.Mech.E.

At the Chamber of Commerce, Birmingham, at 7.30 *p.m.*

21st October—Cold Weather Operation of Aircraft, by G. W. Wilson, A.F.R.Ae.S., M.I.Ae.S., and Squadron Leader E. P. Bridgland, R.C.A.F., A.E., B.Sc., A.F.R.Ae.S., A.F.I.Ae.S.

28th October—Some Developments in Aircraft Production, by D. C. Robinson. (Read by H. Smith.)

11th November—Two French Aircraft Gas Turbines, by M. Destival. (Read by M. Bidard.)

20th November—

FULL DAY DISCUSSION ON HELICOPTERS

(A Joint Meeting with the Helicopter Association of Great Britain)

Morning Session

11 a.m. to 1 p.m.—General Problems of the Helicopter for Civil Use.

11 a.m.—The Operational Point of View, by W/Cdr. R. A. C. Brie, A.F.R.Ae.S., A.F.I.Ae.S.

11.30 a.m.—The Technical Point of View, by Capt. R. N. Liptrot.

12 noon to 1.0 p.m.—Discussion.

Afternoon Session

2.30 p.m. to 4.30 p.m.—The Constructors' Approach to the Problems.

2.30 p.m.—The Fairey "Gyrodyne," by Dr. J. A. J. Bennett, D.Sc., M.A., D.I.C., F.R.Ae.S., F.Inst.P.

3.0 p.m.—The "Bristol 171" Helicopter, by R. Hafner.

3.30 p.m.—The Cierva "Air Horse," by J. S. Shapiro, Dipl.Ing., A.F.R.Ae.S.

4.0 p.m. to 4.30 p.m.—Discussion.

Evening Session

5 p.m. to 6.30 p.m.—General Discussion and summing up by the Lecturers and the Chairman.

25th November—Development of the Armstrong Siddeley Mamba Engine, by W. H. Lindsey, M.A., A.F.R.Ae.S.

2nd December—Problems in the Development of a New Aeroplane, by G. R. Edwards, M.B.E., B.Sc., F.R.Ae.S.

16th December—Present Thoughts on the Use of Power Flying Controls in Aircraft, by D. J. Lyons.

BRANCH LECTURES AND ACTIVITIES

BELFAST BRANCH

6th January—Some Experiences in Experimental Gliding, by Professor Hill, M.C., M.Sc., F.R.Ae.S., M.I.Mech.E.

30th January—Smoking Concert.

3rd February—High Speed Flight, by Dr. Hilton.

24th February—Evening of "Lecturettes."

16th March—Inside Occupied Japan, by William Courtenay, M.M., A.R.Ae.S.
5th October—Annual Meeting.
26th October—The Future Trend of Naval Aviation, by Rear-Admiral M. S. Slattery, C.B., F.R.Ae.S., R.N. (Retd.).
16th November—Some Problems in Civil Aviation, by N. E. Rowe, C.B.E., D.I.C., B.Sc., A.C.G.I., F.R.Ae.S.
7th December—The Weight Aspect in Aircraft Design, by L. W. Rosenthal, A.F.R.Ae.S.
14th December—Evening of Films.

BIRMINGHAM BRANCH

23rd January—Pneumatic Equipment in Aircraft, by C. Hyde, A.R.Ae.S.
5th April—The Development of Stressed Skin Construction, by Dr. D. M. A. Leggett, A.F.R.Ae.S.
11th June—Annual General Meeting followed by members' concert.
8th November—Aircraft Armament, by S. J. Millars.

BRISTOL BRANCH

20th January—Debate.
11th February—The Design of a Large Naval Vessel, by H. S. Pengelley, R.C.N.C., M.Inst.N.A.
23rd February—Accidents and Their Investigation, by Air Commodore Vernon Brown, C.B., O.B.E., M.A., F.R.Ae.S.
3rd March—Reading of Prize-winning Papers by Junior Members.
22nd March—Operation of Civil Transport Aircraft, by N. E. Rowe, C.B.E., F.R.Ae.S.
14th April—Film Night and Annual General Meeting.

BROUGH BRANCH

21st August—Air Display at Brough Aerodrome.
29th September—Modern Wing Section, by E. F. Relf, C.B.E., F.R.S., F.R.Ae.S. At Brough.
27th October—Planned Servicing in the R.A.F., by Sqdn. Ldr. E. A. Harrop. At Brough.
17th November—The Physiological Aspect of Flying, by Sqdn. Ldr. Barwood. At Hull.
15th December—A Film Show. The Bell Helicopter, with commentary by Capt. A. B. H. Youell. At Hull.

COVENTRY BRANCH

15th January—Airscrews, by E. Danvers.
19th February—The Principles of Helicopter Flight, by W. Stewart. A Joint Meeting with the Coventry Engineering Society.
18th March—Pneumatic Systems for Aircraft, by D. Dewar.
16th September—Rocket Flight (M.O.S. Film).
21st October—Development of the Brabazon I, by G. P. Hebden.
18th November—Electronics, by Dr. Whiteley.
9th December—Lecture by E. Smith.

DERBY BRANCH

5th April—Flight Refuelling, by Sir Alan Cobham, K.B.E., A.F.C.
13th September—The Art of the Aviation Engine, by Air Commodore F. R. Banks, C.B., F.R.Ae.S.
4th October—Propeller Gas Turbines, by L. Haworth, B.Sc., A.M.I.Mech.E.
1st November—Fighter Aircraft of the World, by Sqdn. Ldr. H. F. King, M.B.E.
6th December—Annual General Meeting.

GLOUCESTER AND CHELTENHAM BRANCH

15th January—Film on Rocket Flight (Sound track in English). At Gloucester.
4th February—Photographic Reconnaissance Operations, by Group Captain R. C. Field. At Cheltenham.
4th March—A Film on Light Alloy Castings and Forgings. At Gloucester.
7th April—Annual General Meeting followed by Film. At Cheltenham.
30th September—Trend of Jet Engine Development, by A. A. Lombard. At Gloucester.
20th October—Production Methods, by W. W. W. Downing, A.F.R.Ae.S. At Stroud.
18th November—Problems Facing Civil Air Operations, by N. E. Rowe, C.B.E., F.R.Ae.S. At Gloucester.
15th December—Stiffness and Strength, by Professor A. R. Collar, M.A., D.Sc., F.R.Ae.S. At Cheltenham.

GLASGOW BRANCH

27th January—" Lecturettes "—Signalling Systems Used During the Late War, by W. P. Nichol, and With the Lysander in India, by F. W. Burnard.
2nd March—Film Show: How an Aeroplane Flies.
25th March—Lecture and Film Show, by Dr. Hooker. At Hillington.
6th April—Visit to The India Tyre and Rubber Co., Inchinnan.
8th May—Visit to Prestwick Airport.
8th June—Visit to The Glasgow Herald Office.
3rd July—Visit to The Blackburn Aircraft Ltd., Clyde Factory, Dumbarton.
26th August—" Lecturettes."
28th September—A Film Evening.
28th October—Lecture by a Branch Member.
30th November—" Lecturettes."
23rd December—Annual General Meeting.

HATFIELD BRANCH

10th March—Annual General Meeting.
21st April—Direct Disc Recording, by C. E. Watts.
19th May—Film—Atomic Physics.
16th June—The Development of the Brabazon I, by G. P. Hepden, B.Sc., A.C.G.I., D.I.C.
14th July—Selection of Aeronautical Films.
13th October—Aircraft Photography, by John Yoxall.
17th November—Design Problems of Large Flying Boats, by H. Knowler, F.R.Ae.S.

ISLE OF WIGHT BRANCH

15th October—Inaugural Dinner.
11th November—" Lecturettes "—Four short talks on Production.
2nd December—The Development of the Armstrong Siddeley " Mamba " Engine, by W. H. Lindsey, M.A., A.F.R.Ae.S.
16th December—Annual General Meeting and Film Show.

LEICESTER BRANCH

18th February—Film Evening.
10th March—Structural Testing, by Dr. P. B. Walker, Ph.D., M.A., F.R.Ae.S.
22nd September—What Future for the Light Aeroplane Industry, by R. E. Bird.
14th October—A Novice Abroad with Aeroplane and Camera, by J. Rice.
10th November—Leonardo da Vinci, Aeronautical Engineer, by H. J. Penrose.
24th November—Films.
8th December—Discussion on Light Aero-Engines, led by J. Gadd, E. Mitchell and W. B. Mathison.

LUTON BRANCH

7th January—Discussion Evening.
4th February—Some Problems in Civil Aviation, by N. E. Rowe, C.B.E., B.Sc., D.I.C., F.R.Ae.S.
3rd March—Operation of Aircraft from the Pilot's Point of View, by Flying Officer J. N. B. Boyd.
24th March—Discussion Evening.
7th April—Rocket Propulsion and Inter-Planetry Flight, by A. V. Cleaver, A.R.Ae.S.
5th May—Large Flying Boats, by H. Knowler, F.R.Ae.S.
2nd June—Discussion Evening.
1st September—Gas Turbine Accessory Systems, by O. N. Lawrence, A.F.R.Ae.S.
6th October—Accident Investigation, by Air Commodore Vernon Brown, C.B., O.B.E., M.A., F.R.Ae.S.
20th October—Presidential Address by the Branch President, P. Ll. Hunting, Comp.R.Ae.S., and Discussion Evening.
3rd November—Materials of Aircraft Construction and Material Processing, by Dr. Sutton.
1st December—The Light Aeroplane and the Future of Private Flying, by P. G. Masefield, M.A., F.R.Ae.S.

MANCHESTER BRANCH

29th January—Pressurisation, by G. Beardshall.
26th February—Naval Aircraft, by Captain Fancourt.
1st April—Flight Refuelling, by C. H. Latimer-Needham.
23rd September—Engineering Problems of Ultra-Light Aircraft, by A. R. Weyl, A.F.R.Ae.S.
13th October—Some Aspects of Power Plant Design, by Dr. E. W. Still, Ph.D., B.Sc., A.C.G.I., A.F.R.Ae.S., A.M.I.Mech.E.
25th November—Recent Developments in Flying Boats, by H. Knowler, F.R.Ae.S.
15th December—Lightning, by Dr. F. R. Perry, M.Sc.(Tech.), M.I.E.E.

PORTSMOUTH BRANCH

2nd January—Wind Tunnels, Open and Closed Types, by D. W. Bottle.
6th February—Developments in Propeller-Turbine Engines, by Davies—All-wing Type of Aircraft, by Keen.
24th September—Flight Refuelling, by C. H. Latimer-Needham, F.R.Ae.S.
22nd October—Lighter-than-Air Craft, by Lord Ventry, Companion R.Ae.S.
26th November—Model Section Display.
3rd December—Films showing " How an Aeroplane Flies."
17th December—Some Aspects of Carrier Operation, by Capt. (E) B. H. Cronk, D.S.C., R.N.(Retd.).

PRESTON BRANCH

7th January—Problems of High Speed Flight, by D. L. Ellis, B.Sc., A.R.T.C., F.R.Ae.S.
28th January—Photographic Interpretation of the Bomber Offensive against Germany, by S/Ldr. G. A. Morris, O.B.E.
10th March—Bird Flight, by Captain J. L. Pritchard, Hon.F.R.Ae.S.
15th September—The Development of the Brabazon I, by G. P. Hebden, B.Sc., A.C.G.I., D.I.C., F.R.Ae.S.
29th September—The Application of Air Forces in the Second World War, by Wing Cdr. V. C. Varcoe, O.B.E.
27th October—Design Problems of Large Flying Boats, by H. Knowler, F.R.Ae.S.
17th November—On the Investigation of Aircraft Accidents, by Air Commodore Vernon Brown, C.B., O.B.E., F.R.Ae.S.
8th December—Gusts, by Professor A. A. Hall, M.Sc., M.A., F.R.Ae.S.

SOUTHAMPTON BRANCH

7th January—Rotating Wing Aircraft, by C. G. Pullin, F.R.Ae.S.
4th February—The Principles of Air Frame Strength Testing, by P. B. Walker, M.A., Ph.D., F.R.Ae.S.
3rd March—A Survey of Fighter Handling Qualities, by J. K. Quill, O.B.E., A.F.C.
13th October—Civil Aviation—Present and Future, by P. G. Masefield, M.A., F.R.Ae.S.
10th November—Aircraft Production, by S. E. H. Lefever.
8th December—Rocket Propulsion and Interplanetry Flight, by A. V. Cleaver, A.R.Ae.S.

WEYBRIDGE BRANCH

13th February—Dance.
15th September—Presidential Address by the Branch President, G. R. Edwards, M.B.E., B.Sc., F.R.Ae.S., A.M.I.Struct.E., and Discussion Evening.
6th October—Rocket Propulsion and Interplanetry Flight, by A. V. Cleaver, A.R.Ae.S.
27th October—High Speed Wind Tunnels, by E. J. Richards, M.A., B.Sc., A.F.R.Ae.S., and E. Smyth, B.Sc., A.F.R.Ae.S.
17th November—Some Aspects of Practical Flying, by J. K. Quill, O.B.E.
1st December—The Island Campaign (Coloured film), shown by W. Courtenay, M.M., A.R.Ae.S.
15th December—Annual General Meeting, followed by films of Vickers Aircraft.

YEOVIL BRANCH

12th February—The Probable Role and Influence of Aircraft in Future Warfare, by Air Marshal Sir Robert H. M. S. Saundby, K.B.E., C.B., M.C., D.F.C., A.F.C.
25th February—Helicopter Aerodynamics and Mechanics, by O. L. L. Fitzwilliams, B.A.
11th March—Title to be fixed; P. G. Masefield, M.A.(Eng.), F.R.Ae.S.
25th March—Recent Developments in Flying Boats, by H. Knowler, F.R.Ae.S.
1st April—Annual General Meeting and Film.

GRADUATES' AND STUDENTS' SECTION

The following committee was elected at the Section's Annual General Meeting on the 21st April 1948:—

Chairman—J. W. F. Housego, Esq., Graduate.
Vice-Chairman—J. G. Roxburgh, Esq., Graduate.
Committee—M. K. Bowden, Esq., Student; P. F. N. Edwards, Esq., Student; R. G. Evans, Esq., Student; P. T. Fink, Esq., Graduate; G. B. Griffiths, Esq., Graduate; A. N. McDonald, Esq., Student; T. H. Marsden-Jones, Esq., Student; J. R. Miller, Esq., Graduate.
Hon. Secretary—M. C. Campion, Esq., Graduate, 6a Mildenhall Road, Clapton, London, E.5.
Assistant Hon. Secretary—D. A. Thurgood, Esq., Student, 81 Bourne Avenue, Hayes, Middlesex.

LECTURES

20th January—Films of the helicopter, lent by the Bell Helicopter Co. Commentary by Captain Cyril Turner, A.F.C.
10th February—Stability and Control Problems, by D. J. Lyons.
25th February—Suction Aerofoils, by B. Thwaites.
14th April—The Influence of the Recent Civil Airworthiness Requirements on Civil Aircraft Design, by W. Tye, B.Sc., F.R.Ae.S.
11th May—The Light Aeroplane and the Future of Private Flying, by P. G. Masefield, M.A., F.R.Ae.S.

28th September—Sailplane Design, by K. G. Wilkinson, B.Sc., A.C.G.I., D.I.C., A.F.R.Ae.S.
26th October—Flight Refuelling, by Sir Alan J. Cobham, K.B.E., A.F.C., Hon.F.R.Ae.S.
10th November—Flying Experiences, by Lt. Cdr. (A) E. M. Brown, O.B.E., D.S.C., A.F.C., M.A., A.R.Ae.S., R.N.
24th November—The Investigations of Aircraft Accidents, by Air Commodore Vernon S. Brown, C.B., O.B.E., M.A., F.R.Ae.S.
21st December—Production, The Dynamics of People at Work, by J. V. Connolly, B.E., A.F.R.Ae.S.

VISITS

10th July—D. Napier & Son Ltd.
20th July—Royal Aircraft Establishment, Farnborough.
14th August—The National Physical Laboratory, Teddington.
28th August—Vickers-Armstrongs Ltd. (Aircraft Section), Weybridge.
8th September—The Ford Motor Company, Dagenham, Essex.
25th September—Northolt Airport, Ruislip, Middlesex.

HONORARY FELLOWSHIPS

The following were awarded Honorary Fellowship of the Society in 1948:—
Sir Geoffrey Taylor—Yarrow Research Professor at the University of Cambridge.
Dr. Theodore von Kármán—Professor of Aeronautics at the California Institute of Technology and U.S. Army Chairman of the A.A.F. Scientific Advisory Board.
Sir Alliott Verdon-Roe, O.B.E.—Fellow of the Society, President of Saunders-Roe Ltd.
Mr. H. O. Short—Fellow of the Society, Honorary Life President of Short Brothers.

MEDALS AND AWARDS

The following medals, awarded by the Council, were presented at the 36th Wilbur Wright Memorial Lecture on 27th May 1948.

Society's Gold Medal

The Society's Gold Medal, the highest honour the Society can confer, has been awarded to Professor Sir Bennett Melvill Jones, C.B.E., A.F.C., F.R.S., Hon.F.I.Ae.S., F.R.Ae.S., for his outstanding work in Aerodynamics.

Society's Silver Medal

Awarded for some advance in aeronautical design, to I. I. Sikorsky for his work on the development of the Helicopter.

Society's Bronze Medal

Awarded for some advance in aeronautical design, to Miss F. B. Bradfield, O.B.E., M.A., F.R.Ae.S., for her work on aeronautical research.

The British Gold Medal for Aeronautics

Awarded for an achievement leading to advancement in aeronautical science, to E. W. Hives, C.H., M.B.E., Fellow, for his work on aero-engine development.

The British Silver Medal for Aeronautics

Awarded for an achievement leading to advancement in aeronautical science, posthumously awarded to Robert Kronfeld, A.F.C., Associate Fellow, for his gliding achievements.

Simms Gold Medal

Awarded annually for the best paper read in any year before the Society on any science allied to aeronautics such as meteorology, wireless telegraphy, instruments, and so on, to Sir William T. Griffith, D.Sc., F.R.I.C., F.Inst.P., F.I.M., for his paper, "The Problem of High Temperature Alloys for Gas Turbines."

George Taylor (of Australia) Gold Medal

Awarded for the most valuable paper submitted or read during the previous session, to Dr. J. W. Drinkwater, B.Sc., Wh.Sc., and W. G. Glendinning, B.A., A.F.R.Ae.S., for their paper on "The Risk of Fire and Fire Prevention Methods."

Edward Busk Memorial Prize

Awarded for the best paper received on some subject of a technical nature connected with aeroplanes, to Air Marshal the Hon. Sir Ralph Cochrane, K.B.E., C.B., A.F.C., for his paper on "The Development of Air Transport During the War."

R.38 Memorial Prize

Awarded for the best paper on some subject of a technical nature in the science of aeronautics, to W. M. Widgery, F.R.Ae.S., for his paper on "Pressurisation of Aircraft."

Branch Prize

Awarded for the best paper on an aeronautical subject read before the Branches of the Society jointly to, A. N. Clifton, F.R.Ae.S., for his paper on "Naval Aircraft" read before the Southampton Branch, and J. A. Kirk for his paper on "Wind Tunnels" read before the Belfast Branch.

WAKEFIELD GOLD MEDAL

The Wakefield Gold Medal was presented to Mr. Edwin A. Link on 17th December 1947 at the U.S. Chamber of Commerce in Washington, immediately before the reading of the Eleventh Wright Brothers Lecture by Professor Sydney Goldstein, F.R.Ae.S. The presentation was made by Air Chief Marshal Sir Guy Garrod, K.C.B., O.B.E., M.C., D.F.C., on behalf of the British Ambassador in Washington.

BADEN POWELL MEMORIAL PRIZE

The Baden Powell Memorial Prize was awarded to Aircraftsman H. S. Liner who was considered by the examiners to be the best candidate in the December 1947 Associate Fellowship examinations, and to Mr. A. Powell, Student Member of the Society, the best candidate in the June 1948 examinations.

ELLIOTT MEMORIAL PRIZE

The Elliott Memorial Prize was awarded to 582280 Milne, W. C., Fitter II (E) —Cpl./App./Air, the Aircraft Apprentice of the February 1945 Entry, who obtained the highest marks in the General Studies Examination, and to 582494 Ellis, D., Fitter II (E)—Sgt./App./Air, the Aircraft Apprentice of the August 1945 Entry, who obtained the highest marks in the General Studies Examination.

BUSK STUDENTSHIP IN AERONAUTICS

The Busk Studentship in Aeronautics for the year 1948-9 was awarded to Arthur John Cable, a Student Member of the Society, of the Merchant Venturers' Technical College, Bristol University.

JOURNAL PREMIUM AWARDS

The following premium awards for 1947 were made by the Council for papers published in the Journal:—

R. K. Page, B.Sc., A.F.R.Ae.S., Performance Calculation for Jet-Propelled Aircraft. Twenty pounds. May 1947 Journal.

Professor F. Panlilio, The Theory of Limit Design applied to Magnesium Alloy and Aluminium Alloy Structures. Twenty pounds. June 1947 Journal.

P. B. Walker, M.A., Ph.D., F.R.Ae.S., Mechanical Vibrations and Aeroelasticity. Fifteen pounds. April 1947 Journal.

Lt. (A) (A/E) T. E. G. Bowden, R.N., Grad.R.Ae.S., Design for Maintenance. Ten pounds. March 1947 Journal.

W. Tye, B.Sc., F.R.Ae.S., Gusts. Ten pounds. September 1947 Journal.

F. W. Morgan, B.Sc., A.R.Ae.S., High Speed Aircraft Flying Limitations and Handling Problems. Ten pounds. September 1947 Journal.

L. Malavard, The Use of Rheo-electrical Analogies in Certain Aerodynamical Problems. Ten pounds. September 1947 Journal.

L. W. Rosenthal, A.F.R.Ae.S., The Influence of Aircraft Gross Weight upon the Size and Weight of Hulls and Fuselages. Ten pounds. November 1947 Journal.

M. J. Kemper, M.B.E., A.R.Ae.S., Maintenance Difficulties in the Field. Ten pounds. December 1947 Journal.

ROYAL AERONAUTICAL SOCIETY DATA SHEETS

The Royal Aeronautical Society has prepared data sheets on Aerodynamics and Stressed Skin Structures for the use of all technicians engaged in aviation.

Aerodynamic data sheets, numbering 68, are available at £3 1s. 0d. for a complete set to members and £5 8s. 0d. for a complete set to non-members of the Society. These sheets give information and data on most aerodynamical problems connected with aircraft.

Stressed Skin Structure Data Sheets, numbering 123, are available at £5 14s. 0d. to members and £10 5s. 6d. to non-members.

A full list of sheets may be obtained from the Secretary, The Royal Aeronautical Society, 4 Hamilton Place, London, W.1.

CONVERSAZIONE

On 29th October 1948, the President (Dr. H. Roxbee Cox, D.I.C., F.R.Ae.S., F.I.Ae.S.) and the Council of the Society held a Conversazione in the Science Museum (Aeronautical Section), South Kensington.

Some 400 members and their guests were present and were received by the President and Mrs. Roxbee Cox. During the evening Dance Music was played for those who wished to dance and films of the early days of aviation and of bird flight were shown. Because of the large number of members and their guests present the films were shown twice.

A sound film entitled "The First Ten Years of Flying" was shown first. It included early flights in Europe and America, including the Santos Dumont airship of 1901 and the Santos Dumont aeroplane of 1906, Esnault Pelterie, Delagrange and Henri Farman in 1907, Kaferin in 1906, the Wright Brothers in 1908 and at Le Mans and St. Louis in 1909, Glenn Curtiss in 1908 and 1909, and Bleriot's cross-Channel flight in 1909.

The next two dealt with the two stages of development of the Lee-Richards Annular Monoplane, showing first the machine gliding at Kirby Lonsdale in 1912 and then power flying with one of the Annular machines at Shoreham in 1913.

Mr. G. Tilghman Richards gave a running commentary. The next film showed the return of the R.100 from Canada.

The " Story of the Helicopter " was shown through the courtesy of Captain R. N. Liptrot who also gave a commentary on it. It showed the development of the helicopter from earliest times, including Da Vinci's Notebook, Sir George Cayley, the Moineau Paddle Wheel, Passat Ornithopter, an early Paddle Wheel, early French, German and Italian efforts, Sikorsky's first attempt in 1909, the development of the Cierva Autogyro right up to the modern Sikorsky Helicopters of to-day.

The last film showed Pelicans in Flight.

The Council wish to thank particularly Mr. G. Tilghman Richards, Captain R. N. Liptrot, Sir Archbold Sinclair (for the Lee-Richards film), and the Shell Refining and Marketing Co. Ltd. (for the film The First Ten Years of Flying).

The following members and their guests were present at the Conversazione:—

Mr. and Mrs. C. F. Abell; Mr. and Mrs. F. N. Aldridge and guests; Mr. J. R. Anderson and guest; Mr. and Mrs. R. L. Anthony; Mr. and Mrs. E. J. N. Archbold; Mr. L. S. Armandias.

Air Commodore and Mrs. F. R. Banks, Miss Christine and Miss Ann Robin Banks; Dr. and Mrs. A. Buchanan Barbour; Mr. A. Barclay; Miss F. E. Barwood and guest; Mr. and Mrs. E. L. Bass; Mr. and Mrs. H. Bateman; Mr. F. W. N. Bassett; Mr. and Mrs. D. Baxter; Wing Commander and Mrs. R. P. Beamont; Miss J. Bower; Mr. E. C. Bowyer; Mrs. F. D. Bradbrooke and guests; Mr. and Mrs. J. W. S. Brancker; S/Ldr. and Mrs. E. J. Brandon; Mr. and Mrs. W. K. Brasher; Dr. and Mrs. L. G. Brazier; Mr. and Mrs. R. A. Bridgeman; Colonel W. A. Bristow and guests; Mr. Charles Brown; Mr. H. Brittlebank and guest; Mrs. Brogli and guest; Mr. H. V. and Mr. B. C. Bullbrook; Major and Mrs. G. P. Bulman; Sir John and Lady Buchanan.

Mrs. A. Calvert; Mr. S. Camm; Mr. and Mrs. J. D. Campbell; Mr. Basil Cardew; Mr. and Mrs. R. H. Chaplin; Mr. and Mrs. Graham Clark; Mr. A. V. Cleaver; Mr. A. N. Clifton; Mr. A. C. Clinton and guest; Sir Alan and Lady Cobham; Air Marshal the Hon. Sir Ralph and the Hon. Lady Cochrane; Mr. J. C. Collins; Mr. H. G. Conway; Major and Mrs. J. L. B. H. Cordes; Mr. and Mrs. Wm. Courtenay; Dr. and Mrs. H. Roxbee Cox; Mr. and Mrs. F. F. Crocombe and guests.

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and Mrs. P. V. Hoare; Mr. and Mrs. A. J. Hughes; Mr. and Mrs. G. Hughes; Mr. V. A. M. Hunt and guest; Mr. and Mrs. B. J. Hurren; Mr. A. Hurstfield.

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The London Editor "Yorkshire Post"; Mr. J. Yoxall.

RECEPTIONS

Receptions were held by the President, Dr. H. Roxbee Cox, and Mrs. Roxbee Cox, supported by the Council, at 4 Hamilton Place on the 17th and 24th January 1948. Some 300 members and guests were present on each day.

At these receptions members were given an opportunity of seeing for the first time most of the more interesting parts of the valuable Hodgson-Cuthbert Collection, which was presented to the Society by Sir Frederick Handley Page towards the end of 1947.

HODGSON-CUTHBERT COLLECTION

The Hodgson-Cuthbert Collection was begun about 1820 by John Cuthbert, believed to have been a philosophical instrument maker of Lambeth. He acquired a remarkable collection of fine engravings, many in contemporary colouring. Cuthbert also collected fragments of famous balloons, including a precious specimen of the fabric of the historic balloon in which Pilatre de Rozier made the first ascent into the atmosphere in 1783. In addition he also gathered together a number of rare contemporary books and scarce pamphlets, news-cuttings, posters and handbills of flights.

On Cuthbert's death the collection was apparently acquired by John Fillinham and in later years it passed into the hands of G. E. Dering, an electrical engineer, and in 1917 the Aeronautical Collection formed by Cuthbert was sold *en bloc* at Hodgson's Auction Rooms in Chancery Lane. The Collection was bought by Mr. J. E. Hodgson in 1919 for presentation to the late Air Commodore E. M. Maitland, as a gift from his friends to commemorate the historic flight of the R.34 to New York and back. Air Commodore Maitland would not accept a memento which he could not share with his comrades and the Collection remained with Mr. Hodgson, who added to it a number of rare books, engravings, autographs and newscuttings. In 1947, through the generosity of Sir Frederick Handley Page, the Collection was acquired by the Society.

The Collection comprises about 125 volumes of early books on flying, including Geoffrey of Monmouth's "Chronicle" of 1508 recording the legendary flight of Bladud; some 443 rare and fine prints, engravings, acquatints and mezzotints, portraits and caricatures; some 250 posters, handbills and tickets advertising balloon ascents by Charles Green between 1821 and 1852 and others relating to John Hampton, the Grahams, Harris, Gale and others; modern English, French, Italian and German books and pamphlets dealing with historical and technical aspects of aeronautics, and a number of fragments of balloon fabrics.

ACKNOWLEDGMENTS

The Council gratefully acknowledge the following:—

A letter from Sir Ross Smith, from W. Fitch, Esq.

"The Cody Flyer," from R. H. Bound, Esq., F.R.Ae.S.

A collection of specially bound historical and technical books in English, French and German, from Lord Nathan.

A collection of lantern slides and slide cabinets, from Sir Oliver Simmonds.

A model of a Handley Page Halifax, from F. A. Hughes & Co. Ltd.

Books, Publications, Catalogues and Periodicals from: J. W. Bateman, Esq., Associate; Miss A. D. Betts; P. J. Duncton, Esq., Associate Fellow; Mrs. Kronfeld; the Ministry of Supply Library; the National Physical Laboratory Library; the Royal Aero Club; P. H. Wilkinson, Esq.; H. J. Wolffsohn, Esq., and W. A. Woodward, Esq.

Back numbers of the Journal from: C. M. Barter, Esq., Associate Fellow; D. S. Bliss, Esq., Student; A. B. Carr, Esq., Associate Fellow; F. H. Henstock, Esq., Associate; D. D. Jones, Esq., Associate; J. R. Lander, Esq., ex-Student; Major B. W. Shilson, Fellow; J. D. L. Stratton, Esq., Associate Fellow; T. E. Voss, Esq., ex-Student; F. D. Ward, Esq., Graduate; D. Wilde, Esq., Associate Fellow and A. Williamson, Esq., Associate Fellow.

REVIEW

Gas Turbines and their Problems. Hayne Constant, M.A., F.R.Ae.S., M.I.Mech.E. Todd Publishing Group Ltd., London. 158 pp. Illustrated. 7s. 6d. net.

Hayne Constant at the time he wrote this book was the Deputy-Director of the National Gas Turbine Establishment. He has now succeeded Dr. Roxbee Cox as Director and the latter will undoubtedly offer his brilliant assistant new varieties of fuel for the Constant flame. It is to be hoped, however, that the new Scientific Advisor to the Ministry of Fuel and Power and the new Director will not forget Emerson's comment "A creative economy is the fuel of magnificence."

In his foreword the author, pointing out that practical achievement has outstripped the basic principles and underlying theory of the gas turbine, adds "At the present time, therefore, the structure of the gas turbine is undergoing a process of underpinning."

The author himself was as much the cause of practical achievement outstripping theory and it is therefore all the more important that he should be responsible for publishing a book on the state of the art as it is at present.

This is a first-class book, first class not only because it is written by a technician who has a superb confidence in his own knowledge and judgment and therefore is an enthusiast, but by one whose past achievements entitle him to the attention which should be paid to anything he may have to say on the gas turbine. Who but the author, indeed, would have said "The gas turbine in fact is not an engine; it is a system," and then proceed to develop the statement so clearly and concisely that one has no doubt whatever that all present forms of engine will undoubtedly give way to a system.

The author is that excellent mixture of the over-heated enthusiast and the efficiently cooled expert which enables him to give the pros of the gas turbine with such force that the reader is almost indignant to read "The next few years are likely to be full of disappointments for those who believe in the eventual widespread use of the gas turbine."

Many of the more experienced designers of other forms of prime movers were accused of pessimism when they cast doubts on the nearness of the gas turbine millennium and the author must be congratulated for coming down so definitely on the disappointing side of the turbine fence. But it will only be to rise again, for when one clearly faces difficulties those difficulties are by that very action lessened.

This is a book in its early stages, which, revised and brought up to date as experience permits, should be in the hands of all those who are interested in the use of power in one of its most economical (ultimately) forms. The difficulties facing the increasing use of the gas turbine are not those solely of operating experience and component design. Some of the difficulties are inherent in the system involving such a variety of thermodynamic cycles that some definite choice must be made—and that choice is a difficult one.

Nevertheless the reviewer agrees with the last two lines of this intriguing book "We may confidently expect to see the gas turbine gradually assert itself to become the most important form of heat engine known to man."

Contents: Early History; The Advent of the Aircraft Gas Turbine; The Present Position of the Gas Turbine; Thermodynamic Cycles; The Compressor; The Turbine; Ducting; Combustion; The Heat Exchanger; Mechanical Design; Applications of the Gas Turbine; The Future.

an appreciation

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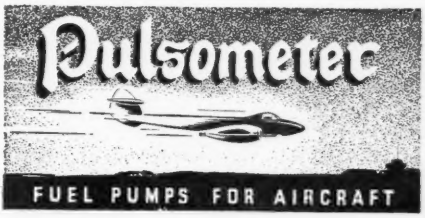

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British Aluminium Co. Ltd.	Salisbury House, London Wall, E.C.2.	Clerkenwell 3494
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British Belting and Asbestos Ltd.	Cleckheaton, Yorks.	Cleckheaton 800
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	Headquarters: Airways House, Berkeley Sq., W.1.	Mayfair 8400
	Traffic Enquiries: Airways Terminus, Victoria	Victoria 2323
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de Havilland Aircraft Co. Ltd., The	Hatfield Aerodrome, Herts.	Hatfield 2345
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Fairey Aviation Co. Ltd.	Hayes, Middlesex	Hayes 3800
Firth-Vickers Stainless Steels Ltd.	Staybrite Works, Sheffield	Sheffield 41193
Folland Aircraft Ltd.	Hamble, Southampton, Hants.	Hamble 3191
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	Kelvin Works, Basingstoke	Basingstoke 690
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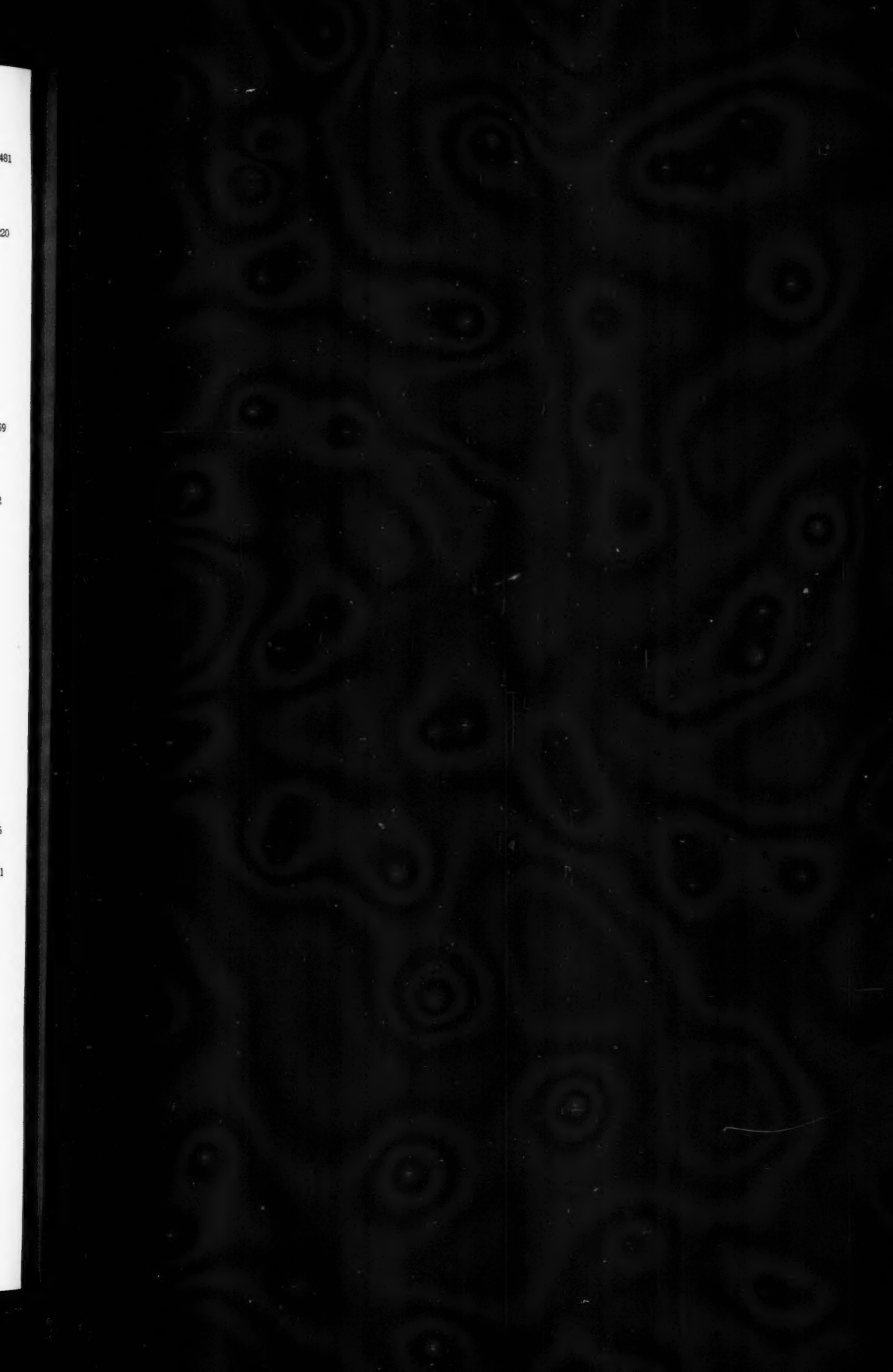

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THE ROYAL AERONAUTICAL SOCIETY
4 HAMILTON PLACE PICCADILLY LONDON W1

JANUARY NOTICES 1949

NEW YEAR

The President and Council extend to all members at home and overseas their best wishes for the year 1949.

CONTENTS OF THE JANUARY JOURNAL

Cold Weather Operation of Aircraft, by G. W. Wilson, A.F.R.Ae.S., M.I.Ae.S., and Squadron Leader E. P. Bridgland, R.C.A.F., A.E., B.Sc., A.F.R.Ae.S., A.F.I.Ae.S.
Some Developments in Aircraft Production, by D. C. Robinson.
Helicopter Hovering Performance, by C. M. Britland, D.Ae., Grad.R.Ae.S.
Summary of the Activities of the Society—January-December 1948.

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the Journal and hope that members (or non-members) will contribute papers on their own special subjects.

ANGLO-AMERICAN AERONAUTICAL CONFERENCE

The following preliminary details of the programme for the Anglo-American Conference to be held in America in May and June 1949 give a general idea of the programme:—

The 23rd May will be an Open Day at the Institute of the Aeronautical Sciences. The technical sessions will be from 24th May to 27th May. The British papers for the technical sessions have been arranged as follows:—

Paper	*Author*
The Relative Merits of Auxiliary Power Systems:—	
Hydraulic	H. G. Conway
Electric	R. H. Woodall
Pneumatic	H. R. Haerle
Turbine-Engined Transport Aircraft	G. R. Edwards
Research on Helicopters at the R.A.E. with special reference to the Stability of Multi-Rotor Helicopters	H. B. Squire
Materials from the Designers' Point of View	A. E. Russell
Operational Use of Propeller Gas Turbines	F. M. Owner
The Application of Materials from the Manufacturers' Point of View	Major P. L. Teed
The Relative Efficiencies of Large Landplanes and Flying Boats	D. Keith Lucas
The Life of Aircraft Structures	H. A. Wills
Some Considerations of the Flutter Problems of High Speed Aircraft	E. G. Broadbent
Operating Factors Affecting the Design of Civil Aircraft	C. Dykes

An equal number of American papers on subjects covering the field of Aeronautics will be included in these sessions.

Following the technical sessions a week of visits to plants and Government Laboratories has been arranged. Among the visits arranged are:—

Langley Memorial Aeronautical Laboratory in Virginia.
The Patuxent Air Station, the Navy's Test Station.
The Naval Aircraft Factory in Philadelphia.
Republic Aviation Corporation.
Grumman Aircraft Engineering Corporation.
Curtiss-Wright Corporation, Engine and Propeller Divisions.

It is expected that other visits can be arranged nearer to the time of the Conference. Members who propose to attend the Conference should inform the Secretary as quickly as possible.

ASSOCIATE FELLOWSHIP EXAMINATIONS

Candidates are reminded that a new Associate Fellowship Examination syllabus came into force on 1st January 1949, but that papers will continue to be set in the old syllabus up to and including December 1949. Entry forms for the May examination under the old syllabus must be in by 28th February 1949.

Candidates wishing to enter for Part I in the New Syllabus must send in their entry forms by 31st January 1949 for the May examination.

ANNUAL SUBSCRIPTIONS OF MEMBERS

Members are reminded that their annual subscriptions became due on 1st January 1949. The rates are:—

	Home	Abroad
	£ s. d.	£ s. d.
Fellows	5 5 0	4 4 0
Associate Fellows	4 4 0	3 3 0
Associates	*3 3 0	*3 3 0
Graduates (aged 21-25)	2 2 0	2 2 0
Graduates (aged 26-28)	2 12 6	2 12 6
Students (aged under 21)	1 1 0	1 1 0
Students (aged 21 and over)	1 11 6	1 11 6
Companions	3 3 0	3 3 0
Founder Members	2 2 0	2 2 0

* Any Associate elected before 1st October 1947 may, if he wishes, elect not to receive the Journal, and in this case his subscription will be reduced by £1 1s. 0d.

It will avoid delay and confusion if members, when sending remittances for subscriptions, will state their names clearly and give their addresses and grades of membership.

Remittances should be made payable to either the Royal Aeronautical Society or Aerial Science Ltd.

MEMBERS' NEW APPOINTMENTS

Peter G. Masefield, M.A., Fellow—Assistant to the Chairman and General Manager, British European Airways.

W. R. McGraw, Associate Fellow—Director of Aircraft Production, Ministry of Supply.

LECTURE PROGRAMME—SPRING 1949

Unless otherwise stated, lectures will be held at 6 p.m. in the Lecture Hall of the Institution of Civil Engineers, Great George Street, London, S.W.1 (by permission of the Council of the Institution). Tea will be served at 5.30 p.m.

Thursday, 13th January 1949—The Auto Pilot, by F. W. Meredith, B.A., F.R.Ae.S.

Thursday, 27th January 1949—Radar as an Aid to the Study of the Atmosphere, by Dr. F. E. Jones, M.B.E., B.Sc., A.M.I.E.E.

Thursday, 10th February 1949—THE SECOND LOUIS BLERIOT LECTURE: French Practical Aerodynamic Methods, by Monsieur Brocard and Monsieur Hussenot.

Thursday, 17th February 1949—Planned Servicing in the Royal Air Force, by Sqdn. Ldr. E. A. Harrop, O.B.E., A.F.R.Ae.S.

Thursday, 24th February 1949—Flutter and Stability, by Professor W. J. Duncan, B.Sc., F.R.Ae.S., M.I.Mech.E., F.R.S.

Saturday, 5th March 1949—FULL DAY DISCUSSION ON AIR SAFETY.

Morning Session 11 *a.m.*—1 *p.m.*

The Theoretical Aspects of Airworthiness and Safety, by J. D. North, F.R.Ae.S.

The Physiological Aspects of Safety, by Dr. K. G. Bergin, M.A., M.D., A.F.R.Ae.S.

1 p.m.—2.30 p.m.—Luncheon Interval (Members should make their own arrangements).

Afternoon Session 2.30 *p.m.*—4.30 *p.m.*

Safety from the Pilot's View Point, by Captain J. W. G. James, O.B.E.

Operational Research into Air Traffic Control, by Dr. G. E. Bell, M.Sc.

4.30 p.m.—5 p.m.—Tea Interval (Tea will be provided at the Lecture Hall).

Evening Session 5 *p.m.*—6.30 *p.m.*

General Discussion and summing-up by the Lecturers and the Chairman.

Thursday, 17th March 1949—The Design of Propellers, by J. Mullin, B.Sc.(Eng.), A.F.R.Ae.S., and C. G. I. Gardiner.

Tuesday, 22nd March 1949—JOINT MEETING WITH THE AIRPORT ENGINEERING DIVISION OF THE INSTITUTION OF CIVIL ENGINEERS.

Tea at 5 *p.m. Lectures at* 5.30 *p.m.*

Aircraft Design with Special Reference to the Restrictions Imposed by Considerations in Airfield Design, by P. H. Watson, B.Sc., A.F.R.Ae.S.

The Problem of Airfield Design in Relation to Aircraft Design, by C. E. Foster, C.B.E., B.Sc.(Eng.), A.M.I.C.E.

Thursday, 31st March 1949—Repeated Loading of Aircraft Structures, by Dr. P. B. Walker, M.A., F.R.Ae.S.

Thursday, 7th April 1949—Investigation of Aircraft Accidents in Relation to Aircraft Design, by Air Commodore Vernon Brown, C.B., O.B.E., M.A., F.R.Ae.S.

Thursday, 21st April 1949—High Lift Devices and Their Use, by R. R. Duddy, A.F.R.Ae.S.

(*At the Portsmouth Municipal College at* 7 *p.m.*)

Thursday, 28th April 1949—THE THIRTY-SEVENTH WILBUR WRIGHT LECTURE:—

The Aeronautical Research Scene—Goals, Methods and Accomplishments, by Dr. Hugh Dryden, F.R.Ae.S., Director of Aeronautical Research to the National Advisory Committee of Aeronautics.

GRADUATES' AND STUDENTS' SECTION—LECTURE PROGRAMME 1949

Thursday, 3rd February 1949—Notes on Fighter Development 1936-1948, by Jeffrey K. Quill, O.B.E., A.F.C., Senior Test Pilot, Vickers-Supermarine Ltd.

Wednesday, 2nd March 1949—The Development of the Brabazon I, by G. P. Hebden, A.F.R.Ae.S., Bristol Aeroplane Co. Ltd.

Wednesday, 23rd March 1949—Annual General Meeting of the Section.

Wednesday, 6th April 1949—The Trend of Jet Engine Development, by A. A. Lombard, A.F.R.Ae.S., Chief Designer (Projects), Rolls-Royce Ltd.

Tuesday, 19th April 1949—The Meaning and Measurement of Stability Derivatives, by P. T. Fink, B.E., Grad.R.Ae.S., Imperial College.

Thursday, 12th May 1949—Pressure Cabins, by D. Cardwell, B.Sc., A.C.G.I., A.F.R.Ae.S., Royal Aircraft Establishment.

Meetings will be held in the Library of the Royal Aeronautical Society, 4 Hamilton Place, W.1, at 7.30 p.m. *The Library will not be open before* 7 *p.m.*

BELFAST BRANCH

Tuesday, 11th January 1949—One Thousand Miles an Hour, by Professor G. T. R. Hill, M.C., M.Sc., F.R.Ae.S., M.I.Mech.E.

Tuesday, 1st February 1949—The Propeller-Turbine Aero-Engine, by F. M. Owner, M.Sc., F.R.Ae.S., M.S.A.E.

Tuesday, 22nd February 1949—Three Lecturettes, by Branch Members, followed by an informal discussion.

Tuesday, 8th March 1949—Helicopter Design, by T. E. Goligher, B.Sc., D.I.C., A.F.R.Ae.S.

Tuesday, 22nd March 1949—A Lecture, by P. G. Masefield, M.A., F.R.Ae.S., M.I.Ae.S., G.I.Mech.E. (Title to be announced later.)

Friday, 8th April 1949—General Meeting.

Lectures will be held in the Central Hall, College of Technology, Belfast, at 7 p.m.

BIRMINGHAM BRANCH

Saturday, 8th January 1949—Annual Dinner and Concert.
At the Woodman Inn, Paradise Street, Birmingham, 7.0 p.m. for 7.15 p.m.

Wednesday, 26th January 1949—Branch Presidential Address by the President, Dr. S. C. Redshaw, F.R.Ae.S.
At the Birmingham Chamber of Commerce, at 7.30 p.m.

BROUGH BRANCH

Wednesday, 19th January 1949—Lecturette Programme, by Members of the Brough Branch. *At Brough.*

Wednesday, 16th February 1949—Jet Engines, by W. T. Winter, The de Havilland Engine Co. Ltd. *At Hull.*

Wednesday, 16th March 1949—Aerodynamics, by J. R. Ewans, B.A. Ltd., Aerodynamics Staff. *At Brough.*

Wednesday, 13th April 1949—The Brabazon Aircraft, by F. H. Pollicut, Bristol Aeroplane Co. Ltd. *At Hull.*

Lectures at *Brough* are held at the Flying Club, at 5.45 p.m.

Lectures at *Hull* are held in the Lecture Hall, Electricity Showrooms, Ferensway, at 7.30 p.m.

COVENTRY BRANCH

Thursday, 20th January 1949—Development of the Mamba Engine, by W. H. Lindsey, Armstrong Siddeley Motors Ltd.

Thursday, 17th February 1949—The London-Sydney Air Route, by C. H. Jackson, B.O.A.C.

Thursday, 17th March 1949—The Automatic Pilot, by A. I. O. Davies, Smiths' Aircraft Instruments Ltd.

Thursday, 28th April 1949—Annual General Meeting and Film.
All lectures will be held in the Old Gulson Library, Coventry, at 7.30 p.m.

DERBY BRANCH

Monday, 7th February 1949—Pictures in the Air, by Charles E. Brown, F.I.B.P., A.R.P.S.

Monday, 7th March 1949—Helicopters—The Technical Point of View, by Capt. R. N. Liptrot, C.B.E., B.A.

Monday, 4th April 1949—Rocket Propulsion and Inter-Planetary Flight, by A. V. Cleaver, A.R.Ae.S.

Monday, 2nd May 1949—Lubrication of Aero Gas Turbines, by J. G. Dawson, B.Sc., A.F.R.Ae.S.

Meetings will be held at the Rolls-Royce Welfare Hall, Nightingale Road, Derby, at 6.15 p.m.

GLOUCESTER AND CHELTENHAM BRANCH

Thursday, 20th January 1949—Weather Forecasting in Aviation, by B. C. V. Oddie, B.Sc., Senior Meteorological Officer, R.A.F. Eastern Avenue, Barnwood. *At Gloucester.*

Wednesday, 16th February 1949—The Design of an Aeroplane, by Professor R. L. Lickley, B.Sc., D.I.C., F.R.Ae.S. *At Cheltenham.*

Thursday, 3rd March 1949—Electrical Aircraft Instruments, by E. B. Moss, B.Sc., F.Inst.P., M.I.Mech.E. *At Gloucester.*

Wednesday, 30th March 1949—Radar Aids in Aeronautics, by Dr. S. F. Evans, M.Sc., Ph.D. *At Cheltenham.*

Thursday, 21st April 1949—Annual General Meeting. Followed by Film, Atomic Physics. *At Gloucester.*

All meetings are held at 7.30 p.m. unless otherwise notified.

Gloucester Meetings (Thursdays) are held in the Wheatstone Hall, City Library, Brunswick Road. *Cheltenham Meetings* (Wednesdays) in the Chemistry Lecture Theatre, Grammar School (entrance off Oxford Passage).

HATFIELD BRANCH

Wednesday, 12th January 1949—Blind Landing Technique, by J. W. F. Mercer, B.Sc., A.C.G.I.

Wednesday, 16th February 1949—The Probable Role and Influence of Aircraft in Future Warfare, by Air Marshal Sir Robert Saundby, K.B.E., C.B., M.C., D.F.C., A.F.C.

Wednesday, 16th March 1949—Annual General Meeting.

All meetings will be held at 6.15 p.m. in the de Havilland Senior Staff Mess.

ISLE OF WIGHT BRANCH

Thursday, 20th January 1949—Aircraft Design from the Airline Point of View, by C. Dykes, M.A., M.Sc., M.S.Ae., M.I.Ae.S.

Thursday, 3rd February 1949—The Probable Role and Influence of Aircraft in Future Warfare, by Air Marshal Sir Robert Saundby, K.B.E., C.B., M.C., D.F.C., A.F.C.

Thursday, 24th February 1949—Naval Aircraft, by Lieut. Commander E. M. Brown, O.B.E., D.F.C., M.A., A.F.R.Ae.S.

Thursday, 10th March 1949—A Lecture, by N. E. Rowe, C.B.E., D.I.C., B.Sc., F.R.Ae.S. (Provisional.)

Thursday, 24th March 1949—Brains Trust.

Meetings will be held in the Sports and Social Club, Saunders-Roe Ltd., East Cowes, Isle of Wight, at 6 p.m.

LEICESTER BRANCH

Wednesday, 12th January 1949—Bird Flight and the Aeroplane, by Captain J. L. Pritchard, Secretary, Royal Aeronautical Society.

Wednesday, 9th February 1949—Airscrews, by E. Danvers, Rotol Ltd.

Wednesday, 9th March, 1949—Charter Flying, by Squadron Leader Wright, Wright Aviation Ltd.

Wednesday, 23rd March 1949—Films.

Wednesday, 13th April 1949—Annual General Meeting and Members' Papers.

Meetings will be held in Room 104, College of Technology, The Newarkes, Leicester, at 7.15 p.m.

LUTON BRANCH

Friday, 7th January 1949—The Light Aeroplane and the Future of Private Flying, by P. G. Masefield.

Wednesday, 2nd February 1949—Discussion Evening.

Wednesday, 2nd March 1949—Evolution of a Modern Aeroplane, by Professor R. L. Lickley, B.Sc., D.I.C., F.R.Ae.S.

At the George Hotel, Luton, at 7.30 p.m.

MANCHESTER BRANCH

Thursday, 27th January 1949—Flight Testing of Civil Aircraft, by P. A. Hufton, M.Sc.

Thursday, 24th February 1949—The Development of the Mamba Engine, by A. S. Lindsey, M.A., A.F.R.Ae.S.

Thursday, 17th March 1949—Personal Experiences of Early Aerodynamic Research, by Professor Sir B. Melvill Jones, C.B.E., A.F.C., F.R.S., Hon.F.I.Ae.S., F.R.Ae.S.

Thursday, 28th April 1949—Rocket Propulsion and Interplanetary Flight, by A. V. Cleaver, A.R.Ae.S.

All lectures will be held in the Reynolds Hall at the College of Technology, Manchester, at 7.30 p.m.

PORTSMOUTH BRANCH

Friday, 14th January 1949—Rocket Propulsion, by A. V. Cleaver, A.R.Ae.S.

Friday, 11th February 1949—Short papers by members of the Branch.

Friday, 11th March 1949—The " Debunking " of Aeronautical Sciences, by C. G. Grey, F.M.R.Ae.S.

All lectures will be held in the Lecture Hall at the Central Library, Guildhall Square, Portsmouth, at 7 p.m.

SOUTHAMPTON BRANCH

Wednesday, 12th January 1949—Gliding, by A. H. Yates, B.Sc., A.F.R.Ae.S.

Wednesday, 9th February 1949—Radio Aids, by F. R. Wills.

Tuesday, 8th March 1949—A Lecture, by A. G. Pugsley, O.B.E., D.S.C.

The lectures will be held in the Physics Lecture Theatre, University College, Southampton, at 7 p.m.

WEYBRIDGE BRANCH

Friday, 28th January 1949—Annual Dance, Oatlands Park Hotel.

Wednesday, 9th February 1949—Civil Air Transport, by P. G. Masefield, M.A., F.R.Ae.S., M.I.Ae.S., G.I.Mech.E., Ministry of Civil Aviation.

Wednesday, 9th March 1949—Air Force Requirements and their Origins, by Air Commodore G. W. Tuttle, C.B., C.B.E., D.F.C., Director of Operational Requirements.

Wednesday, 30th March 1949—Junior Prize Lecture, by a Branch Member.

Wednesday, 27th April 1949—Present-Day Problems in Safety Requirements, by W. Tye, O.B.E., B.Sc., F.R.Ae.S., Air Registration Board.

Wednesday, 18th May 1949—Historical Review of Aircraft Development, by Sir Frederick Handley Page, C.B.E., F.R.Ae.S.

Meetings will be held at Vickers-Armstrongs Ltd., Weybridge Works, at 6 p.m., unless previous notice is given.

AERODYNAMICISTS

Applications are invited by the Ministry of Supply from Aerodynamicists for unestablished appointments in the following grades at the Royal Aircraft Establishment, Farnborough:—

Senior Scientific Officer	Salary range	£670-£860
Scientific Officer	,, ,,	£380-£620
Senior Experimental Officer	,, ,,	£705-£895
Experimental Officer	,, ,,	£495-£645
Assistant Experimental Officer	,, ,,	£220-£460

Rates for women are somewhat lower.

Candidates for the first two grades must have a good Honours degree in mathematics, physics or engineering. Appointment in these grades carries F.S.S.U. benefits.

For the other grades, High School Certificate or its equivalent (a National Certificate could be accepted) is the basic qualification.

Write quoting A.428/48/A to the Ministry of Labour and National Service, Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, for application form, *which must be returned completed by 29th January* 1949.

JOURNAL BINDING

The new prices of binding of Journals will be as follows:—

1948 Volume	14s. 6d.	(including packing and postage)
Previous Volumes ..	16s. 0d.	,, ,, ,, ,,
Cases for 1948 Volume	6s. 0d.	,, ,, ,, ,,

Journals should be sent direct to the Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the Offices of the Society.

Requests for cases, with remittances, should be sent to the Secretary at the Offices of the Society.

CHANGES OF ADDRESS

To assist in keeping the records of members correct and up to date the Secretary will be glad if all members will notify him as soon as possible of changes of address.

When notifying changes please give the following particulars:—

Name (in block letters).
Grade of membership.
New address (in block letters).
Old address.

Changes of address must be received *before the 15th of the month* in order to be effective for the Journal for the following month.

NEW MEMBERS

Associate Fellows

Peter Llewellyn Bisgood, Kenneth Francis Brading (from Student), Wilfred Henry Bunting, Stacey Walter Drury Colls, Hugh Haslett Eccles (from Graduate), Edward Eric Fenn, John Fletcher, Ronald Fowkes (from Graduate), Charles Gurney, Leslie Austin Hancox (from Associate), Emlyn George Havard (from Graduate), Ronald Edwin Victor Hawker, William Alfred Hibbert, David Ivan Hunt, Edgar Harold Jenkins, Jacques Alecxis Kirk (from Associate), Aubrey Frederick Walter Langford, Roy Henry Laver (from Associate), Tung Chi Lin (from Graduate), Llewellyn Lloyd-Davies, Imaduddin Mohammad Khan Malik, John Mulligan (from Associate), Daniel John McDonald, Vernon Dalrymple Naylor (from Graduate), William Thomas Nicholls, Peter Ovadias, Stanislaw Edmund Pozowski (from Associate), Dennis Martin Sealey, Donald Stanley Snow, Colin George Stocker, Philip Litherland Teed, James William Richards Twyman (from Graduate), Robert Philip Urry, Robert Thomas Wall (from Graduate), Joseph Wilkinson (from Associate).

Associates

Douglas Giosue Andreoli, William Leslie Berridge, Aubrey Charles Ericsson (from Student), Geoffrey Ivo Gregson, Roger Francis Deans Harris, Ronald Douglas John Hawkes, Leslie Bailey Hewett, Ronald Charles Jude, Piotr Ostaszewski-Ostoja, Hugh Dyas Parr, Edward Joughin Sheeran, Wilfred Ernest Streete, Alistair Macaulay Stephen, John Francis Walsh, Geoffrey Cyril David Warren, Charles Frederick Wills, Ivor Edward Yeates.

Graduates

Douglas Raymond Andrews (from Student), Peggy Irene Frances Bright, Peter Denis Burnett, Lewis Frederick Crabtree, Edward Melbourne Dallimore (from Student), Raymond William Dyke, Colin Faulkner, Terence John Floyd, Dorothy Ida Gwynne, Stuart Charles Haynes (from Student), Donald Malcolm Heughan (from Student), Denis Howe (from Student), Reginald Wallace Langmead, Gideon Maidanik, David Michael Mayne, John Francis Mew (from Student), Douglas Moore (from Student), Ivor Edward Moss, Gilbert Rugg Nicolson, John Rex (from Student), Tecwyn Roberts, Josephine Salmon, John Shackell, Victor Roy Gordon Smith, Graham Neil Stevens, Jerzy Terajewicz (from Student), Alan William Thompson, William John Trotman, Harry Wigman.

Students

John George Austin, Beryl Edna Beadle, Stanley Forsyth Borrie, Roy Burley Chesterton, Maurice Hubert Reginald Clark, Edward George Clegg, Geoffrey Montague Coiley, Donald Stephen Dugdale, Richard John Herbert, Michael Stewart Igglesden, Peter Norman Eckford Jones, Peter Frederick Keeling, Ronald William Prizeman, Harry Nigel Saint, Geoffrey Phillip Ashton Scovell, Richard Alan Sperry, Henry Edward Swann, John Bernard Sparling Prothero Thomas, Laurence David Tye.

Companions

Reuben Druce, Ivor Clarence Rogers, John Gerald Simms, Ladislav Vostatek, Rioty Marshal Winter.

ACKNOWLEDGMENTS

The Council acknowledge with grateful thanks the gift of First Flight Air Mail Covers from Sir A. H. Roy Fedden, Fellow, and back numbers of the Journal from D. F. Horne, Esq., Associate Fellow; E. S. Moult, Esq., Fellow; S. J. Patmore, Esq., Associate; and Miss M. Wilkes (Southlands College).

ADDITIONS TO THE LIBRARY

Pamphlets in italics with location reference following in brackets. Books marked * or ** may not be taken out on loan.

A.a.350—Introduction to High Speed Flight. T. F. Weldon. T. F. Weldon, Ohio. 1948.

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D.a.B.101—Civil Aviation Report 1946 and 1947. Ministry of Civil Aviation. H.M.S.O. 1948.

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G.e.A.119—B.A. Aluminium Paste. British Aluminium Co. Ltd. British Aluminium Co. Ltd. 1948.

I.e.36—Tables of the Bessel Function Yo(x), Yi(x), Ko(x), Ki(x), $0 \leqq X \leqq 1$. U.S. National Bureau of Standards. U.S. Government Printing Office. 1948.

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N.A.C.A. Technical Notes

1499—*The inward bulge type buckling of a monocoque cyclinders. IV—Experimental investigation of cylinders subjected to pure bending. N. J. Hoff, B. A. Boley and S. V. Nardo.*

1503—*Bearing strength of some aluminium alloy rolled and extruded sections. R. L. Moore.*

1532—*A metallurgical investigation of two contour-forged gas-turbine discs of 19-9DL alloy. J. W. Freeman, E. E. Reynolds and A. E. White.*

1533—*A metallurgical investigation of two large discs of CSA alloy. E. E. Reynolds, J. W. Freeman and A. E. White.*

1571—*Effect of afterbody length and keel angle of minimum depth of step for landing stability and on take-off stability of a flying boat. R. E. Olson and N. S. Land.*

1677—*Experimental and calculated characteristics of several high-aspect-ratio tapered wings incorporating NACA 44-series 230-series, and low drag 64-series airfoil sections. T. V. Bollech.*

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2247—*An investigation of the lateral stability of aeroplanes with rudder free. L. W. Bryant and R. W. G. Gandy.*

2258—*Flight tests on the effect of surface finish on wing drag. A. D. Young, J. E. Serby and D. E. Morris.*

The following reports have also been received:—

C.S.I.R. Division of Aeronautics

*Report No. SM.*118.

Publications Scientifiques et Techniques du Ministere de l'Air

*Report No. N.T.*30.

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